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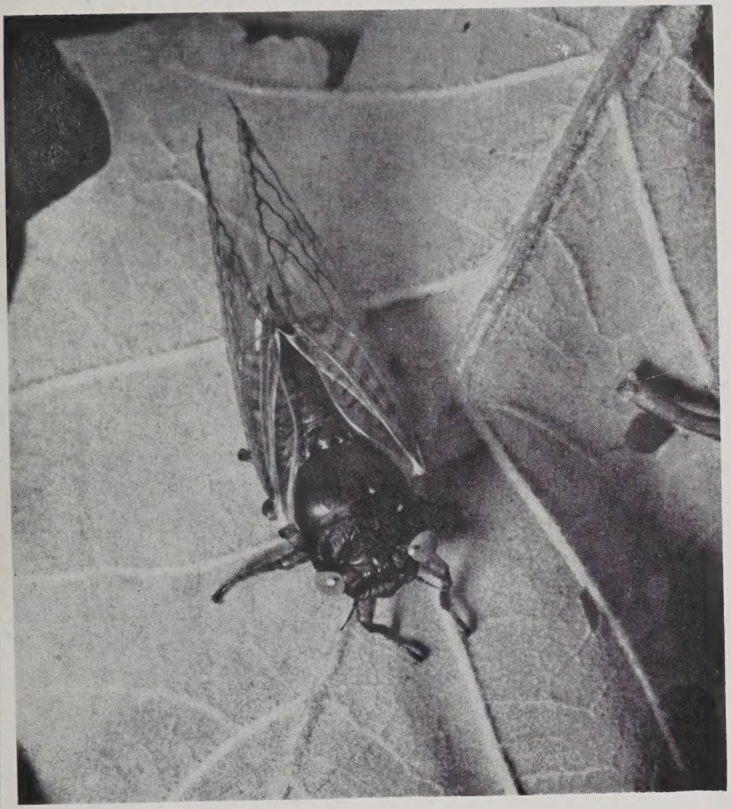
THE DISTRIBUTION OF PERIODICAL CICADAS IN ILLINOIS

Lewis J. Stannard, Jr.



Biological Notes No. 91

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URBANA, ILLINOIS • FEBRUARY, 1975

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The Distribution of Periodical Cicadas in Illinois

Lewis J. Stannard, Jr.

For decades, entomologists have relied upon Marlatt's (1907) compilation of the distribution of the broods of the periodical cicada to forecast emergences of these insects. Such forecasts are especially important to persons concerned with protecting trees and shrubs. Unfortunately, as will be shown in this report, many of Marlatt's records are in error. In their place, a more accurate picture of cicada distribution in Illinois, as observed over the past 10 years, is given here. Additional surveillance of periodical cicadas could be continued profitably to pinpoint exact boundaries of their ranges in some of the central counties of our state, to determine the rates of their dispersal to new areas or extirpation from original areas, and to obtain information on the possibility of introgressive hybridization between broods.

To orchardists, nurserymen, and horticulturists, periodical cicadas are more than mere curious and interesting insects. Even though they occur infrequently (once every 13 or 17 years), they may damage more than 95 percent of the terminal shoots of young fruit trees (Hamilton 1962) or ruin the shapes of specimen trees or choice shrubs. When one considers that as many as 20,000 cicadas may emerge from beneath one apple tree, it is easy to understand how so many twigs can be destroyed during the cicadas' egg-laying process (Hamilton 1962). Trees whose terminal shoots are killed by cicadas usually recover by epicormic branching, according to my observations, but fruit production in orchards can be severely curtailed, causing substantial economic loss.

This report is presented primarily as an aid to fruit growers in making accurate predictions of emergences of periodical cicadas and as a contribution to our basic knowledge of these unusual insects.

ACKNOWLEDGMENTS

I wish to express my appreciation to the staff of the Illinois Natural History Survey, extension entomologists of the University of Illinois, county extension advisers of the state of Illinois, and the many persons in our state who have helped to collect specimens and have shared their observations on the distribution of cicadas over the past 10 years. Without their assistance the state could not have been covered thoroughly in the approximately 3 weeks of the particular years when these insects exist above ground as adults.

My particular thanks are extended to Drs. Thomas E. Moore and Henry S. Dybas for their advice, suggestions, and many favors, especially to Dr. Dybas for reviewing the manuscript. I am further obliged to Mr. Wilmer D. Zehr, who photographed the specimen appearing on the cover; to Mr. Lloyd Le Mere, who prepared the maps; to Mrs. Bernice Sweeney, who typed the manuscript; and to Mr. Robert M. Zewadski, who edited it for publication.

THE ILLINOIS BROODS

With the exception of woods in certain areas that are predominantly sandy (in extreme northeastern Lake County, in eastern Iroquois and Kankakee counties, and in areas in Lee, Ogle, Mason, and a few other counties) almost every wooded section of Illinois is inhabited by a brood of periodical cicadas. Of the five Illinois broods, three have 17-year life cycles and two have 13-year life cycles. A report of their distributions, based mostly on data gathered over the 10 years from 1963 to 1973, is presented here. Documentary notes for this report and the specimens are kept in the collections of the Illinois Natural History Survey (INHS). The research for this report was essentially completed in 1973, and the report was submitted for publication in December 1973.

HISTORICAL RECORDS

One of the first entomologists to record Illinois broods of periodical cicadas was Asa Fitch in 1856. Fitch thought, as did everyone at that time, that all cicada broods in the USA had life cycles of 17 years' duration. The first brood he mentioned as being from Illinois ("Southern Illinois") was the 13-year Great Southern Brood (Marlatt's XIX), which emerged in 1855 simultaneously with an adjacent eastern brood (Marlatt's XIV). Fitch lumped these together as his "third" brood, later analyzed by Walsh & Riley (1868). The other Illinois brood mentioned by Fitch was the 17-year Northern Illinois Brood (Marlatt's XIII) as his "sixth" USA brood. He stated that this brood extended across northern Illinois, ranging as far south as Peoria, in 1854.

Shortly after the appearance of Fitch's work, Cyrus Thomas, the "father" of the Illinois Natural History Survey, learned of records of a third brood of cicadas

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in Illinois, the 13-year Lower Mississippi River Valley Brood (Marlatt's XXIII), which emerged in Union and Jackson counties in 1859. Thomas thought that this brood also had a 17-year life cycle (Thomas 1865:458–459).

In 1868 Benjamin Walsh and C. V. Riley raised the number of Illinois broods to four, adding the 17-year Iowan Brood (Marlatt's III). These authors also suggested that another brood, Marlatt's IV, might occur in Illinois, but this has not proved to be the case. Further, they outlined the range of the Great Southern Brood (Marlatt's XIX) in Illinois, and with few exceptions the range is the same today, according to my 1972 findings.

In the same year, 1868, Riley reported that not all broods had 17-year life cycles but that some had 13-year life cycles. Riley's discovery was made during his study of the Great Southern Brood (Marlatt's XIX), wherein he noted an 1803 record from Alton, Illinois. According to Marlatt (1907), Dr. D. L. Phares of Mississippi probably was the very first, in 1845, to "announce the 13-year period for the southern broods," but because the article was published in a newspaper with local circulation, this notice did not come to the immediate attention of entomologists.

In the following year (1869) Riley published his first annual report on the insects of Missouri and expanded his and Walsh's previous treatment of periodical cicadas by incorporating information from a manuscript written by Dr. Gideon B. Smith of Maryland, then deceased. (This manuscript was published in its entirety by Marlatt in 1898.) From the 16 broods estimated to exist in the USA in 1868, Riley increased the list to 22 broods, changing the numbers of all broods except Brood I. Riley continued his surveillance of periodical cicadas, publishing on them and including Illinois records, until 1894 just before his untimely death from a fall in 1895.

By 1869, therefore, the literature referred to broods numbered separately and differently by Fitch (1856), Walsh & Riley (1868), and Riley (1869). The records included well-documented data as well as mere recollections, some of which were considered questionable at the time and some of which have since proved to be in error.

A couple of years later in 1871, William LeBaron (1872) wrote that "one of the special duties of the State Entomologist of Illinois, in the season of 1871, [was] to determine, as nearly as possible, the range of the present brood, and to make a record of it, which may be consulted by those who may take an interest in this matter, seventeen years hence." His detailed report of the distribution of this brood, the Northern Illinois Brood (Marlatt's XIII), fits well within the broad limits mentioned by Fitch in 1856 and confirmed by my own survey in 1973. LeBaron personally noted the absence of this brood in Mason County, supposedly because of some effects of the sandy soils in this county. However, a Mr. J. Cochrane of Havana, Mason County, convinced LeBaron that a brood emerged in large numbers in Mason County in 1859 or 1860, which LeBaron thought might really be 1861, the year when the Iowan Brood (Marlatt's III) emerged. This supposed emergence, inexactly recalled some 10 years after its alleged occurrence, does not fit with recent data and probably should be discarded as questionable evidence.

It was not until 1885, when Riley made special inquiry of many persons, that the 17-year Great Eastern Brood (Marlatt's X) was proved to occur in Illinois at the eastern border and became the fifth Illinois brood. Some scattered precocious or late emergences of out-of-season broods undoubtedly were included in these Illinois records, but in general, Riley's limitations of the range of this brood in Illinois are the same as those noted in recent years. A sixth Illinois brood, mentioned by Riley in 1885, is probably incorrect, according to my data.

U.S. government entomologists L. O. Howard, C. L. Marlatt, F. M. Webster, M. V. Slingerland, and others became active in the survey of the USA cicada broods in the 1890's and early 1900's. At the Bureau of Entomology, Washington, D.C., at first under Riley, Marlatt eventually took over as the principal compiler of the ranges of the broods. In 1907 (reissued in 1923) Marlatt published what was then the most complete and definitive work on the periodical cicada. In it he compiled all the principal literature and records for each brood, including, unfortunately, the questionable records. He increased the number of broods to 30 even though he considered some doubtful. It was as if Marlatt wanted the total number of broods to equal the sum of the two life cycles (17 + 13), and to achieve this equality, he appeared willing to include any record he could find. Furthermore, he renumbered the broods differently than had Riley in 1869. Generally, Marlatt's numbered designations have been accepted and are in use today. Instead of 30 broods, Alexander & Moore (1962) believe that there may be no more than 18 valid broods in the eastern USA.

S. A. Forbes, head of the predecessor organizations of the Illinois Natural History Survey, his staff, teachers, and others continued to gather data on the Illinois broods and supply Riley, Howard, Marlatt, and others with information. Most of the early cicada specimens, if any were kept, are no longer in the Survey's collections. The Survey has only a few specimens from 1894, a few from the first decade of the 1900's, and a few collected in central Illinois over the next 50 years.

In 1956 the Northern Illinois Brood (Marlatt's XIII) again emerged in high numbers and inspired Henry S. Dybas of the Field Museum of Natural History, Chicago; Thomas E. Moore, then at the Illinois Natural History Survey, Urbana; and Richard D. Alexander, formerly of White Heath, Illinois, to begin new studies on cicadas. Their discoveries caused renewed interest in these insects, opening new types of inquiry and leading to new conclusions on the nature and origin of the possible species involved and the broods. They, along with Monte Lloyd, D. Dwight Davis, and James Heath, made and are making in-depth studies on the exact niches of the species, their songs, and their possible dispersal after deglaciation.

EXCLUDED BROODS

Several broods besides those whose distribution is treated here were purported by Marlatt and others to occur in Illinois. One of these, Marlatt's XIV, was said to extend across the northern border of Illinois. Although observations on periodical cicadas of Illinois have not been regularly made until recent times, the lack of records of this brood in the INHS collections has some significance. Alexander & Moore in 1957 (an emergence year for Brood XIV) did record single specimens in Illinois and Iowa, but they considered these cicadas to be stragglers from the previous year's emergence of the Northern Illinois Brood (Marlatt's XIII) (Alexander & Moore 1962:18). Very few cicadas were found in intensive searches in 1974, and this fact, coupled with the negative evidence of previous years, would indicate that Brood XIV does not, and probably never did, occur in Illinois.

Another brood (Marlatt's XII) reported by Marlatt (1907) to be in Illinois almost certainly does not exist in our state, if indeed it is a valid brood anywhere in the USA. In 1972, when this brood was to emerge, I made repeated trips to Jo Daviess County and neighboring counties, and enlisted the help of naturalists, state park rangers, and landowners in attempts to locate populations of this alleged brood. No cicadas were found. Marlatt, himself, felt that this was a doubtful brood and reported that Forbes had failed to locate it in northwestern Illinois. Probably the records of this brood in Illinois were based on precocious cicadas of the Northern Illinois Brood (Marlatt's XIII) which emerged a year early.

Marlatt's I was recorded by Marlatt (1907) as being questionably present in Madison County, but the Illinois Natural History Survey has no records or specimens of this brood. Alexander & Moore (1962) did not list any Illinois records of this brood, which they studied in detail in the East in 1961.

Marlatt's VI was purported to occur in Illinois from localities where cicadas were said to have emerged in abundance in 1898. In the S.A. Forbes correspondence of 1898 in the archives section of the University of Illinois Library is a request from L. O. Howard of the Bureau of Entomology, Washington, D.C., for cicada information. This request prompted Forbes to send a circular letter to teachers and superintendents of schools asking for data on cicadas emerging in 1898. Besides Forbes, Howard asked other correspondents for information on these cicadas. By June 20, 1898, Howard informed Forbes that he had received a large amount of data from Illinois. The records received by Forbes and Howard from Crawford, Jackson, Jasper, Lawrence, Perry, Pulaski, Union, Wabash, and Wayne counties can be referred to the Lower Mississippi River Valley Brood (Marlatt's XXIII), and this distribution fits well with our present-day records. The other records reported by Howard, especially those supposedly of Marlatt's VI in central Illinois, must be considered doubtful, as we have no specimens in the Natural History Survey collection from this region in 1898 or the following years during which this brood appeared. It should have reappeared in 1966 if it really exists in Illinois, but no observers at the Illinois Natural History Survey have any notes or recollections of this brood's emerging at that time.

THE SPECIES OF PERIODICAL CICADAS

During the years when the surveillance of periodical cicadas was dominated by Riley and Marlatt, it was generally thought that two races existed, the 17-year cicada, *Tibicen* (*Cicada*) *septendecim* (Linnaeus), and the 13-year cicada, *Tibicen (Cicada) tredecim* Riley, with a dwarf form known as *cassini* Fisher. Walsh argued (Marlatt 1907:17; Lloyd & Dybas 1966*b*), and even corresponded with Charles Darwin on the subject, that the 13-year race was an incipient species because the 13-year race and the 17-year race occasionally have opportunities to interbreed; yet no intermediate emergences (14-, 15-, or 16-year intervals) result.

In 1931 Beamer, in 1958 Alexander & Moore (see also Moore & Alexander 1958), and in 1962 Dybas & Lloyd, on the basis of morphological and behavioral distinctiveness, independently arrived at the conclusion that *Magicada septendecim* and *M. cassini* were separate species. In 1962 Alexander & Moore recognized six full species, *M. septendecim, M. cassini,* and *M. septendecula* Alexander and Moore for the 17-year broods, and *M. tredecim, M. tredecassini* Alexander and Moore, and *M. tredecula* Alexander and Moore for the 13-year broods. Apparently no differences exist between the matching pairs of species of the 13- and 17-year broods; they are merely more or less isolated from each other for 13–17 generations.

In Illinois, at least, one 13-year brood, the Great Southern Brood (Marlatt's XIX), is not as isolated from 17-year broods as might be expected. Along the border of the range of this brood, contacts with all of three 17-year broods may occur within 221 years, and contact with one of these three 17-year broods could and possibly does occur every 65 years (five generations) or 78 years (six generations), as indicated in Table 1. If such contacts are made, enough hybridization may occur to prevent isolation of the "incipient species."

TABLE 1. — Dates of simultaneous emergences of a 13-year brood and each of three 17-year broods of periodical cicadas in Illinois. (Mathematically, 65 and 78 are functions of 13.)

Interval in Years	Broods and Years of Emergences			
	Great Southern (XIX) (13-year) 1972	Northern Illinois (XIII) (17-year) 1973	Great Eastern (X) (17-year) 1970	Iowan (III) (17-year) 1963
	1582	1582		
65	1647		1647	
78	1725			1725
78	1803	1803		
221				
65	1868		1868	
78	1946			1946
78	2024	2024		
221				
65	2089		2089	
78	2167			2167
78	2245	2245		
221				

If the matching pairs of 13- and 17-year cicadas are merely phases of the same species, three full species might remain. Each would have its own niche, the small *M. cassini* living on roots of bottomland trees, the large *M. septendecim* living on roots of upland trees, and *M. septendecula,* intermediate between the first two and rarer, developing primarily on hickory and walnut roots (Dybas & Davis 1962; Dybas & Lloyd 1974).

It seems hardly possible that *M. septendecim* is a single species with three forms, resulting from development in separate and different habitats, and with two phases — 13-year and 17-year — primarily resulting from environmental influences. However, the order Homoptera, to which these cicadas belong, is well known for having species that develop highly divergent forms in response to their feeding substrates. Some scale insects, for example *Aspidiotus ancylus* (Putnam), produce divergent forms according to whether they feed on bark or leaves or on certain trees and vines; these forms once were considered to belong to separate genera (Stannard 1965). Some leafhoppers produce forms with radically different types of genitalia, depending on temperature influences (Müller 1957). Even so, the possibility that there is just one species with forms having their own songs, their own times of day for singing, preferences for mating with their own kinds, and their own feeding niches appears remote in the light of our present knowledge and contradicts generally accepted concepts of species.

In this report only the broods will be considered; the nature of the species and their evolution have been well discussed by Lloyd & Dybas (1966*a* and 1966*b*) and Dybas & Lloyd (1974).

STRAGGLER CICADAS

Stragglers from the 13- and 17-year sequence do occur with some frequency. Usually, according to most records, only a few individuals emerge at these off times, and there seems little chance for mating and production of progeny. In 1969, however, a large number of stragglers emerged in the Chicago area. This emergence was of further singularity because it occurred at the close of a 13-year interval in a region where only a 17-year brood was known. Dybas (1969) made an extensive study of these "13-year stragglers" and concluded that he may have had a "ringside seat" along the evolutionary pathway on which 13-year cicadas were derived from 17-year cicadas. He assumed that the cicadas of this particular emergence probably would not develop into a new brood because of the usually cold climate of Chicago. Dybas postulated that the heat effect of the city may have had some influence on these particular stragglers, causing them to emerge so early.

Stragglers that emerge in the fall of the year can be positively identified as deviates, but those that emerge in the regular season (May and June) need to be analyzed with considerable care. These spring stragglers seem to have provided the basis for all the false broods listed by Marlatt and others. Most stragglers emerge early, in the year before the main brood is due.

Supposed Illinois Stragglers

Unless otherwise stated, data refer to single specimens in the INHS collection.

1904. Riverside, Cook County. Possibly not 1907, as given by Alexander & Moore (1962). The last digit appears to be a *4* rather than a 7. This is a possible 1-year-early emergence of the 17-year Northern Illinois Brood (Marlatt's XIII) of 1905.

1932. Urbana, Champaign County, University Woods, September 6. Rocky Branch, Clarksville, Clark County, June 24. These are possibly 1-year-early emergences of the 13-year Great Southern Brood (Marlatt's XIX) of 1933.

1957. Sullivan, Moultrie County, "late in season," H. B. Cunningham, six specimens. This is possibly a 1½-year-early emergence of the 13-year Great Southern Brood (Marlatt's XIX) of 1959.

1969. Lisle, DuPage County, June 6, L. J. Stannard, just emerged at edge of a lowland woods in Morton Arboretum. Chicago Heights, Cook County, June 11, H. B. Petty. Chicago area, many specimens reported to the Natural History Survey extension staff. (See Dybas 1969 for extensive list of localities in the Chicago region.) These are assumed to be 4-year-early emergences of the 17-year Northern Illinois Brood (Marlatt's XIII) of 1973.

1971. Barry, Pike County, June 9, J. Cruttenden, several specimens. Tentatively assigned to *M. tredecassini* by T. E. Moore (personal communication 1971). These are probably 1-year-early emergences of the 13-year Great Southern Brood (Marlatt's XIX) of 1972. Mr. Cruttenden recalls the presence of this brood in the area in 1959.

1972. Lisle, DuPage County, October 12, J. Appleby, one adult next to its shed skin, emerged after flood in Morton Arboretum. This is possibly a half-year-early emergence of the 17-year Northern Illinois Brood (Marlatt's XIII) of 1973.

1973. Mahomet, Champaign County, Nettie Hart Memorial Woods, June 6, M. W. Sanderson. This is a possible 1-year-late emergence of the 13-year Great Southern Brood (Marlatt's XIX) which emerged in 1972.

1974. Lisle, DuPage County, May 29, J. Appleby, one adult on bush. Ohio, Lee County, May 23, Gene R. Kritsky, one adult in flight hit car. These are probably 1-year-late emergences of the 17-year Northern Illinois Brood (Marlatt's XIII).

Other supposed stragglers in the USA have been listed by Alexander & Moore (1962) and in the Chicago area by Lloyd & Dybas (1966*b*).

DISTRIBUTION OF THE BROODS OF ILLINOIS

Because many of Marlatt's broods probably do not exist and because several numbering systems, each differing from the others, have been used, the Illinois broods listed here are designated by geographical names with the corresponding Marlatt numbers for easy reference. These geographical names should be more meaningful than numbers and indicate relationships with populations outside the state.

The Iowan Brood (Marlatt's III)

The Iowan Brood has a 17-year cycle and most recently emerged in 1963. Records (Fig. 1) were obtained from May 26, 1963 along the Spoon River,

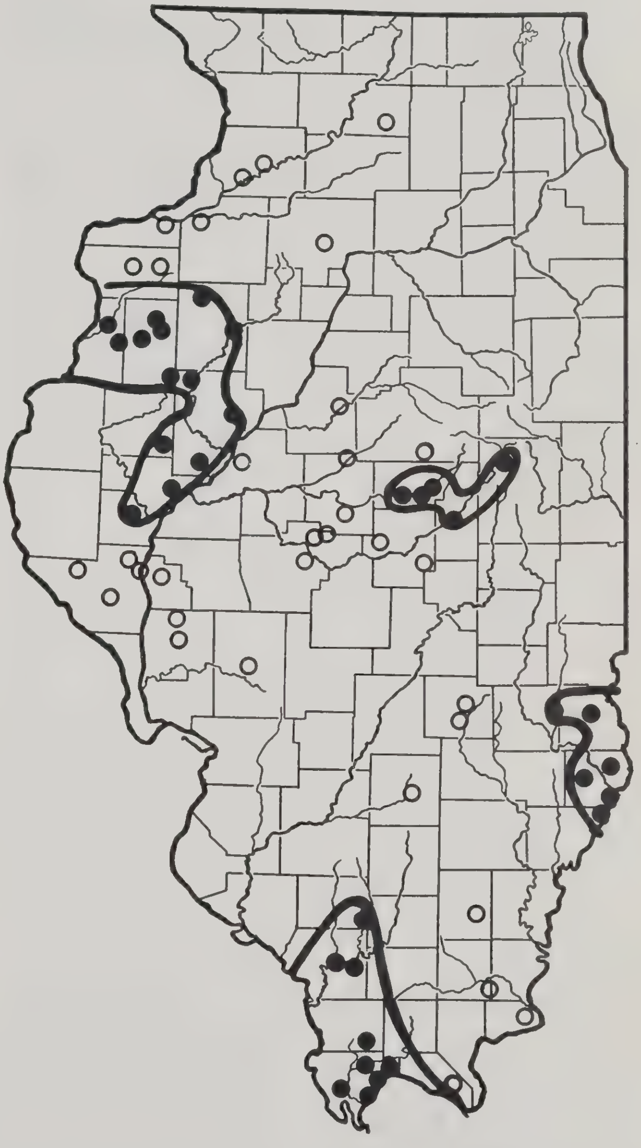

Fig. 1. — Distribution of periodical cicadas in Illinois. The two upper enclosed areas show the locations of the Iowan Brood (Marlatt's III), and the two lower enclosed areas indicate the locations of the Lower Mississippi River Valley Brood (Marlatt's XXIII). Black dots indicate positive records of adult specimens, skins, holes in the ground, flagging tree branches, or singing. Circles indicate negative records in areas carefully searched.

Fulton County, to June 28 in De Witt County. Singing was heard until June 28, also in De Witt County, and flagging (wilted branches that were girdled in the egg-laying process) was noticed on the same date in that county.

Apparently this brood is disjunct in Illinois, the western counties which it inhabits being Brown, Fulton, Henderson, Knox, McDonough, Schuyler, and Warren, and the eastern counties being Champaign, De Witt, and Piatt. Intervening counties, particularly Logan and Mason, did not seem to have populations of these cicadas. In the western counties mentioned and De Witt County large numbers of cicadas emerged, whereas Champaign and Piatt counties had only limited emergences.

This brood must have emerged simultaneously, in 1946, in some instances in adjacent areas or even in the same woods, with the Great Southern Brood (Marlatt's XIX), and these broods will again emerge simultaneously in 2167. Unfortunately, we have no records of the 1946 emergences in the INHS collection. Both broods may occupy the same woods in Champaign County if our records are correctly interpreted. Woods along the Spoon River, Knox County, should be carefully observed in the future to determine whether some of the woods harboring the Iowan Brood also support populations of the Great Southern Brood.

In 1963 Clarence E. White, an INHS entomologist, collected specimens and reported a large emergence in woods at the junction of Illinois 150 and the Spoon River. In 1972 Kent R. Buffington reported in a letter a large emergence in woods north of that area along the Spoon River near Truro, or Williamsfield, as that town is now called. The 1963 population could be assigned to the Iowan Brood and that of 1972 to the Great Southern Brood unless the 1972 emergence was made up of an unusually high number of stragglers of the 1973 Northern Illinois Brood that is known to have colonies nearby.

The Lower Mississippi River Valley Brood (Marlatt's XXIII)

The Lower Mississippi River Valley Brood has a 13-year cycle and last emerged in 1963, the year of the Iowan Brood's most recent emergence. Records in 1963 (Fig. 1) were obtained from late May until the middle of June. In Illinois this brood is also disjunct, being confined to Alexander, Jackson, Perry, Pulaski, and Union counties in the southwest and to Crawford, Jasper, Lawrence, and Wabash counties in the southeast. Several Illinois counties harboring no cicadas of this brood intervene between these populations, but the distribution of this brood probably continues to the south in Kentucky and Missouri. A wide gap exists between the locations of this brood and those of the Iowan Brood within the state.

The Great Eastern Brood (Marlatt's X)

The Great Eastern Brood has a 17-year cycle and most recently emerged in 1970. Although reported to be well distributed along the eastern border of Illinois and even in southern Illinois (Marlatt 1907), in 1970 this brood was found in only a few counties (Vermilion, Edgar, and Clark) despite careful searches elsewhere (Fig. 2). Adults were found from May 21 at Kickapoo State Park, Vermilion County, until June 30, when a small chorus was heard by Dr. R. W. Larimore at nearby Fairmount. A shed skin was found

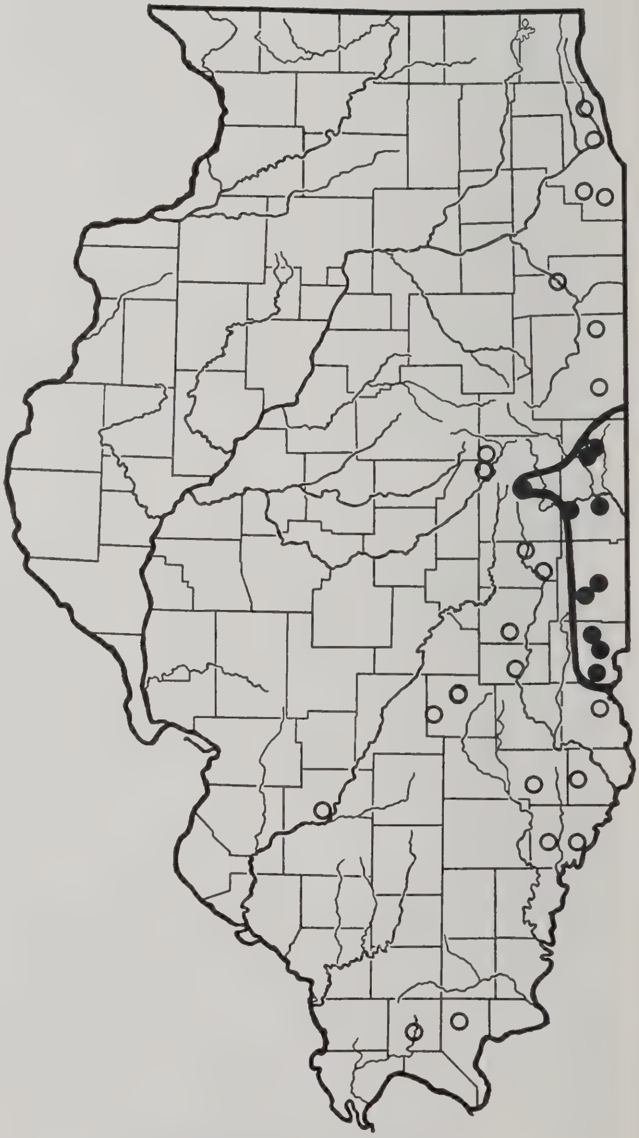

Fig. 2. — Distribution of the Great Eastern Brood (Marlatt's X) of periodical cicadas in Illinois. Black dots indicate positive records of adult specimens, skins, holes in the ground, flagging tree branches, or singing. Circles indicate negative records in areas carefully searched.

in Urbana, Champaign County, on a *Liriodendron* tree, a non-native tree, planted there 8 years previously. Seventeen years earlier in 1953 when this brood emerged, a straggler was also found in Urbana by Dr. R. J. Dysart on August 12. Despite the scanty records in Champaign County, it is possible that the Great Eastern Brood occurred and still persists in small numbers in the Big Grove of Urbana and that eastern Champaign County should be included in the list of counties inhabited by this brood.

The 17-year Great Eastern Brood (Marlatt's X) must have emerged in Illinois adjacent to and at the same time as the 13-year Great Southern Brood (Marlatt's XIX) in 1647 and 1868, and they should appear together again in 2089. Furthermore, the Great Eastern Brood must have emerged adjacent to and at the same time as the 13-year Lower Mississippi River Valley Brood (Marlatt's XXIII) along the border of Clark and Crawford counties in 1664 and 1885, and they should occur together again in 2106.

According to Marlatt (1907) and as reinterpreted by Dybas (1970), this brood has three main but almost certainly disjunct centers: a broad portion of Indiana and western Ohio, a wide area primarily bordering the Mason-Dixon line in Maryland and Pennsylvania, and an area in the southern Appalachians.

The Great Southern Brood (Marlatt's XIX)

The Great Southern Brood has a 13-year cycle and emerged last in 1972. This brood emerges in abundant numbers largely outside the limits of the Wisconsin moraine, except through the east-central region of the state, and outside the areas occupied by the Great Eastern Brood (Marlatt's X) and the Lower Mississippi River Valley Brood (Marlatt's XXIII) (Fig. 3). An isolated colony of "extremely heavy populations of cicadas" was reported to us by K. R. Buffington on May 18–20, 1972 along the Spoon River near Truro, now called Williamsfield, in Knox County. Along the upper Sangamon River in Champaign County both the 13-year Great Southern Brood and adventive or relict colonies of the 17-year Iowan Brood may occur together. In these woodlands in western Champaign County, the Great Southern Brood emerged in greater numbers in 1972 than did the supposed Iowan Brood in 1963.

The 1972 INHS records show that the Great Southern Brood started to emerge as adults as early as May 14 in Pope County, on May 20 in Olney in Richland County, on May 23 at Fox Ridge State Park near Charleston in Coles County, and on May 25 in Piatt County. Singing continued as late as June 30 at Robert Allerton Park near Monticello in Piatt County.

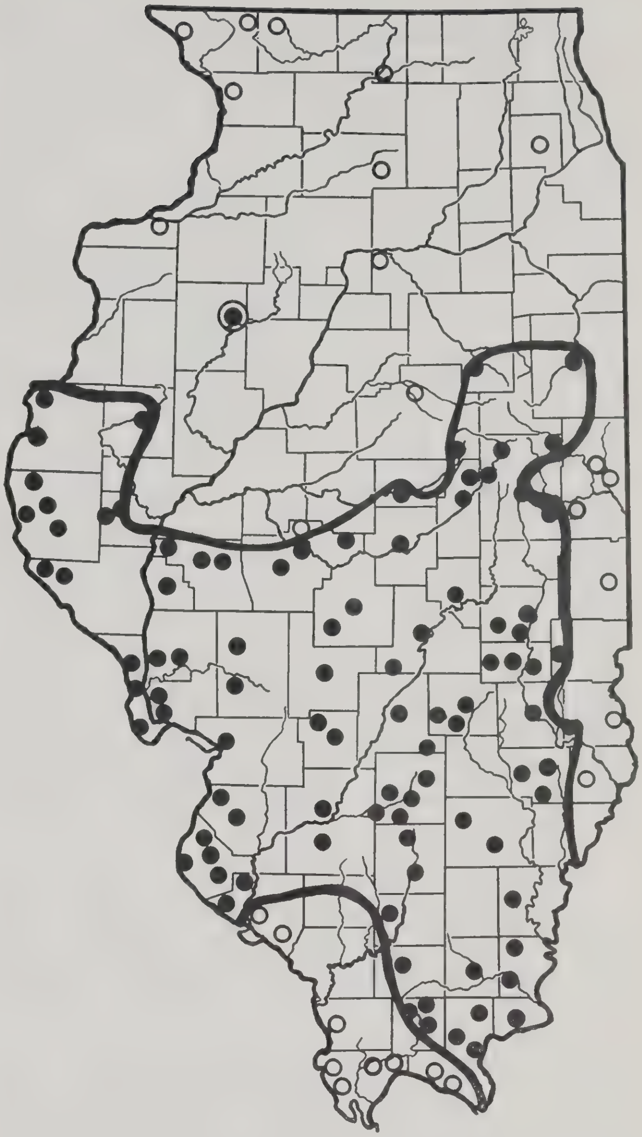

Fig. 3. — Distribution of the Great Southern Brood (Marlatt's XIX) of periodical cicadas in Illinois. Black dots indicate positive records of adult specimens, skins, holes in the ground, flagging tree branches, or singing. Circles indicate negative records in areas carefully searched.

In Illinois the 13-year Great Southern Brood probably emerged adjacent to and at the same time as the 17-year Iowan Brood in 1725 and in 1946, and they should emerge together again in 2167. In the Springfield area the Great Southern Brood probably emerged at the same time as and adjacent to the 17-year Northern Illinois Brood in 1582 and in 1803, and they should emerge together again in 2024. The Great Southern Brood probably emerged simultaneously with the 17-year Great Eastern Brood in 1647 and 1868, and they should do so again in 2089. The opportunity for this 13-year brood to interbreed with these 17-year broods appears highly likely to occur every 65 or 78 years at some part of the Great Southern Brood's total range in Illinois, but only once every 221 years at each specific locality.

A limited number of specimens of this brood were collected in the twin cities of Champaign-Urbana in 1959 and in 1972. They were taken even in those parts of the cities which were originally prairie or were cultivated land less than 25–50 years previously but which are now studded with trees. Moderate singing also was heard by competent observers in both of these years. It would seem, therefore, that colonizing cicadas succeeded in expanding their range at least a few miles into new parklands and that the population level for survival need not be extremely high.

Although bird populations are low in some parts of these cities, where birds are present, cicadas are eagerly sought. In one instance a dozen live cicadas were placed on a hedge in Urbana near a bird-feeding tray. Within 1 minute a blue jay appeared and seized one of the sluggish cicadas. Shortly, this jay returned and was joined by another. All, or at least 11, of the cicadas were quickly taken by the jays; the fate of the last cicada was not determined in the confusion of the jays' visits to the hedge. Other birds, including hawks, were found to have fed heavily on these cicadas in southern Illinois (Dr. R. R. Graber personal communication 1972).

Unpublished reports by Dr. G. W. Bennett indicate that game fish benefited from the abundance of this brood in 1972. Fishes at Fox Ridge State Park, Coles County, fed voraciously on these insects. Cicadas at that site weighed from about ½ gram to nearly a full gram.

The Northern Illinois Brood (Marlatt's XIII)

The Northern Illinois Brood has a 17-year cycle, and its most recent emergence was in 1973. Possibly because a wet, cool spring delayed the emergence, the earliest 1973 records of this brood (Fig. 4) were not taken until May 31 (Tazewell and Sangamon counties) and June 2 (Cook County). Singing was heard in Tazewell County at the end of May and in Jo Daviess, Cook, and Lake counties as late as June 20.

This brood occurs primarily on the Wisconsin glacial drift area except for areas in east-central Illinois. These east-central Illinois regions are occupied by the 13-year Great Southern Brood. Several competent observers noted the absence of this brood from the Zion sand areas in Lake County, and my associates and I failed to find any specimens in the sand areas of Iroquois, Mason, and Lee counties.

The Northern Illinois Brood ranges south to Carpenter Park, north of Springfield, and to Petersburg. Woods south of Springfield and woods near Mechanicsburg showed no evidence of cicadas (specimens, singing, skins, or holes in the ground). During the preceding year, 1972, the Great Southern Brood emerged in these woods (A. L. Koelling personal communication 1973). At the Springfield and Mechanicsburg area, at least, this brood and the 13-year Great Southern Brood probably emerged simultaneously in 1582 and 1803, and will do so again in 2024 and 2245.

The persistence of this brood in old parts of cities was noted in Chicago and Rockford. Mrs. Barbara Fell noted a few skins in her back yard at 819 North

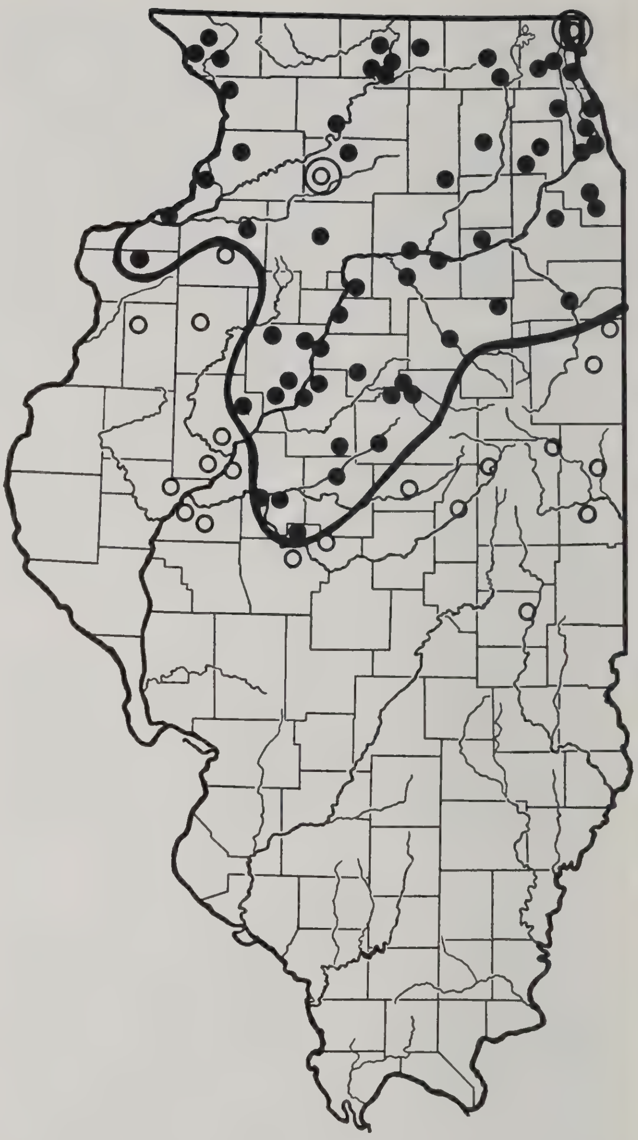

Fig. 4. — Distribution of the Northern Illinois Brood (Marlatt's XIII) of periodical cicadas in Illinois. Black dots indicate positive records of adult specimens, skins, holes in the ground, flagging tree branches, or singing. Circles indicate negative records in areas carefully searched.

Main Street, Rockford, indicating the survival of this brood, despite low numbers, over the past 136 or so years of human occupancy of that city.

In a woods at Castle Rock, Ogle County, the eastern portion contained no cicadas, whereas the western portion, having the same terrain but possibly less sand in the soil, contained a good singing population. There I found adults, skins, and holes in the ground. This observation and others bear out the contention that each woods is not necessarily uniformly inhabited.

FUTURE EMERGENCES OF PERIODICAL CICADAS IN ILLINOIS

Future twentieth-century emergences of periodical cicadas in Illinois are shown in Table 2.

Table 2. — Future twentieth-century emergences of periodical cicadas in Illinois.

Year of Emergence	Brood	Cycle in Years
1976	Lower Mississippi River Valley Brood (Marlatt's XXIII)	13
1980	Iowan Brood (Marlatt's III)	17
1985	Great Southern Brood (Marlatt's XIX)	13
1987	Great Eastern Brood (Marlatt's X)	17
1989	Lower Mississippi River Valley Brood (Marlatt's XXIII)	13
1990	Northern Illinois Brood (Marlatt's XIII)	17
1997	Iowan Brood (Marlatt's III)	17
1998	Great Southern Brood (Marlatt's XIX)	13

DISCUSSION

A composite map of the distribution of the Illinois broods of periodical cicadas is shown in Fig. 5. The borders of the range of each brood are only approximate except in a few regions, as critical areas and woods which should have been put under close surveillance for more precise information could not be recognized until after two or three emergences had been surveyed. In general, the distributions of these broods fit nicely with the distributional patterns of other organisms viewed in relation to geological events. Most of the region occupied by the Northern Illinois Brood lies within the Wisconsin glacial plain. The Iowan Brood, except for the region inhabited by the disjunct population in De Witt, Piatt, and Champaign counties, occupies a western spur on eroded hills of the northern part of the Illinoian glacial plain. The Great Southern Brood, except for the east-central Illinois extension and the corridor in the Shawnee Hills, is mostly on Illinoian glacial plains onto which most of our southern biota also extends. The Great Eastern Brood occupies an area which supports many other relict or adventive eastern species: beech, tulip poplar, and some fishes and salamanders. The Lower Mississippi River Valley Brood occurs for a considerable part in the region where the bald cypress also meets its northern limits.

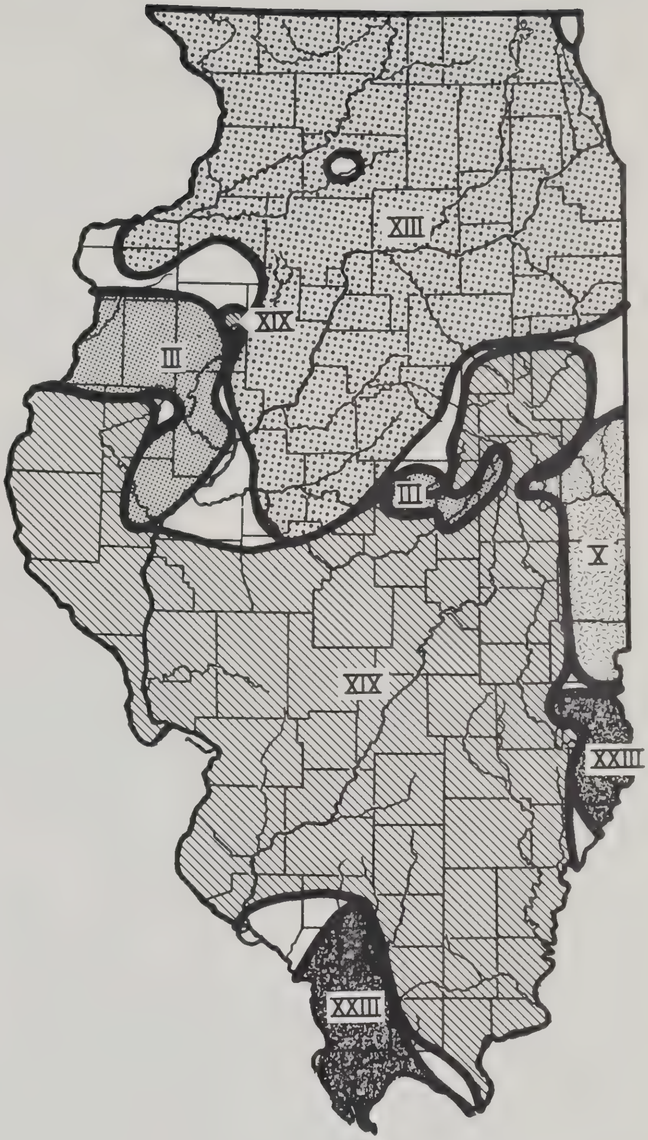

Fig. 5. — Distribution of periodical cicadas in Illinois. The ranges of the five Illinois broods are shown on the map. Each brood is identified by Marlatt's number.

Occupation of a woods by two or more broods is extremely rare, according to my data. Woods can be almost adjacent, but each woods usually supports one brood only. Sand areas are usually, if not always, devoid of cicadas.

The opportunity for 13-year and 17-year broods to meet and hybridize may occur every 65 or 78 years within the total range of the majority of the periodical cicadas of Illinois. It is highly possible that no more than three species exist, each closely regulated by climatic influences producing 13- or 17-year strains, operating under either-or genetic controls.

LITERATURE CITED

ALEXANDER, R. D., and T. E. MOORE. 1958. Studies on the acoustical behavior of seventeen year cicadas (Homoptera: Cicadidae: *Magicicada*). Ohio Journal of Science 58(2):107–127.

———, and ———. 1962. The evolutionary relationships of 17-year and 13-year cicadas, and three new species (Homoptera, Cicadidae, *Magicicada*). University of Michigan Museum of Zoology Miscellaneous Publication 121. 59 p.

BEAMER, R. H. 1931. Notes on the 17-year cicada in Kansas. Kansas Entomological Society Journal 4(3):53–58.

DYBAS, H. S. 1969. The 17-year cicada: A four-year "mistake"? Field Museum of Natural History Bulletin 40(8): 10–12.

———. 1970. Poulation explosion — 17-year locust style. Field Museum of Natural History Bulletin 41(5):11–13.

———, and D. D. DAVIS. 1962. A population census of seventeen-year periodical cicadas (Homoptera: Cicadidae: *Magicicada*). Ecology 43(3):432–444.

———, and M. Lloyd. 1962. Isolation by habitat in two synchronized species of periodical cicadas (Homoptera: Cicadidae: *Magicicada*). Ecology 43(3):444–459.

———, and ———. 1974. The habitats of 17-year periodical cicadas (Homoptera: Cicadidae: *Magicicada* spp.) Ecological Monographs 44(3):279–324.

FITCH, A. 1856. The seventeen-year locust, *Cicada septemdecim*, Linnaeus. Pages 38–49 *in* First and second report of the noxious, beneficial and other insects, of the state of New-York. Albany.

HAMILTON, D. W. 1962. Periodical cicadas, *Magicicada* spp., as pests in apple orchards. Indiana Academy of Science Proceedings 71:116–121.

LEBARON, W. 1872. Periodical cicada. Pages 124–133 *in* Second annual report on the noxious insects of the state of Illinois. Springfield.

LLOYD, M., and H. S. DYBAS. 1966*a*. The periodical cicada problem. I. Population ecology. Evolution 20(2): 133–149.

———, and ———. 1966*b*. The periodical cicada problem. II. Evolution. Evolution 20(4):466–505.

MARLATT, C. L. 1898. The periodical cicada, an account of *Cicada septendecim*, its natural enemies and the means of preventing its injury, together with a summary of the distribution of the different broods. U.S. Department of Agriculture, Division of Entomology, Bulletin 14, new series. 148 p.

———. 1907. The periodical cicada. U.S. Department of Agriculture, Bureau of Entomology Bulletin 71. 181 p.

MOORE, T. E., and R. D. ALEXANDER. 1958. The periodical cicada complex (Homoptera: Cicadidae). Tenth International Congress of Entomology Proceedings, 1956. 1:349–355.

MÜLLER, H. J. 1957. Die Wirkung exogener Faktoren auf die zyklische Formenbildung der Insekten, insbesondere der Gattung *Euscelis* (Hom. Auchenorrhyncha). Zoologische Jahrbücher 85(4/5):317–430.

RILEY, C. V. 1868. "First account ever published of [a 13-year] brood" of the periodical cicada (exact title not known). Journal of Agriculture, St. Louis, June 13, 1868. [This article, not seen, referred to by Riley (1869:19)].

———. 1869. The periodical cicada. Pages 18–42 *in* First annual report on the noxious, beneficial and other insects, of the state of Missouri. Jefferson City.

———. 1885. The periodical cicada. U.S. Department of Agriculture, Division of Entomology Bulletin 8. Second ed. 46 p.

STANNARD, L. J., Jr. 1965. Polymorphism in the Putnam's scale, *Aspidiotus ancylus* (Homoptera: Coccoidea). Entomological Society of America Annals 58(4): 573–576.

THOMAS, C. 1865. Insects injurious to vegetation in Illinois. Pages 401–468 *in* Illinois State Agricultural Society Transactions 5. Springfield.

WALSH, B. D., and C. V. RILEY. 1868. The periodical cicada. American Entomologist 1:63–72.

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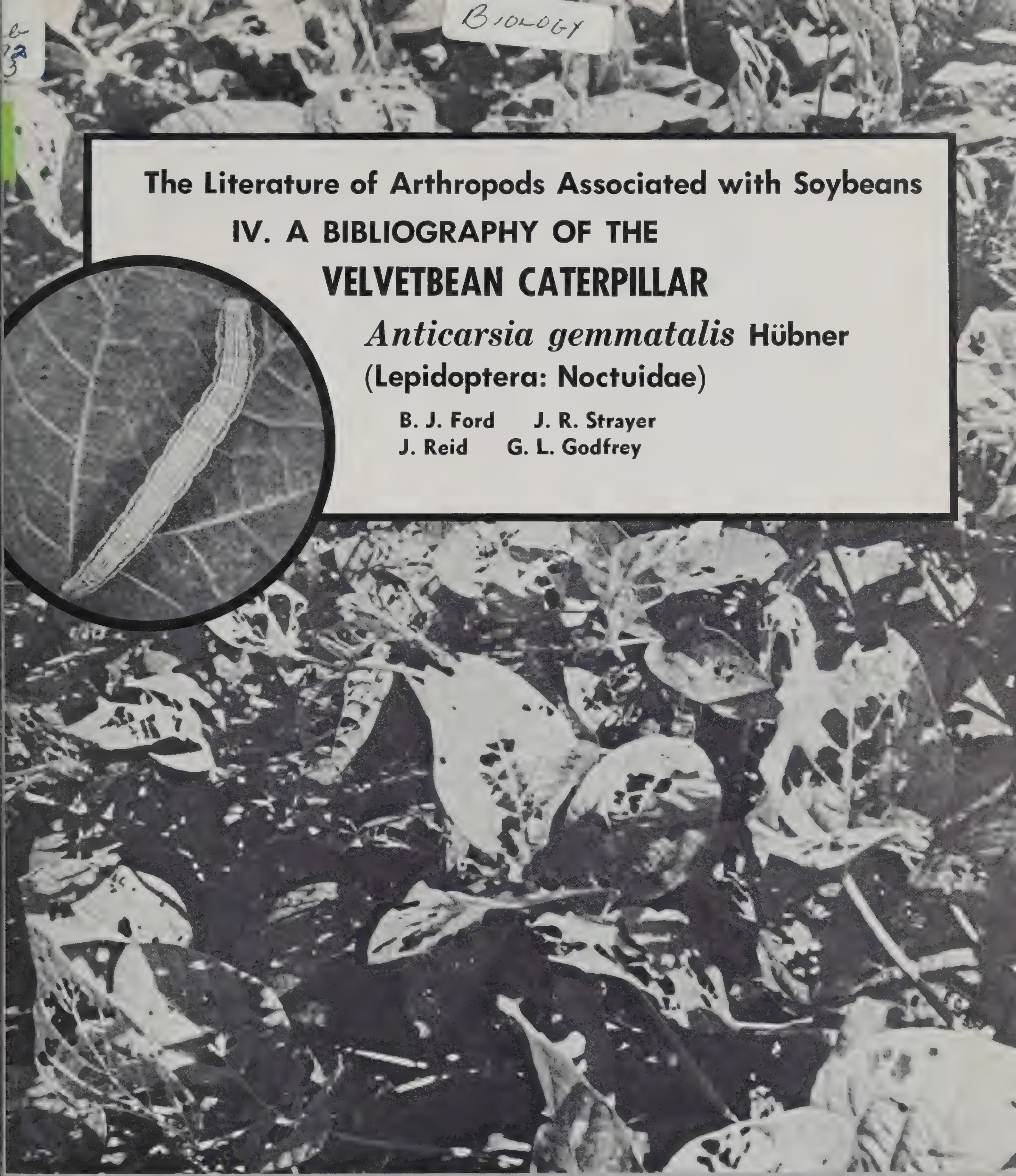

The Literature of Arthropods Associated with Soybeans

IV. A BIBLIOGRAPHY OF THE

VELVETBEAN CATERPILLAR

Anticarsia gemmatalis Hübner
(Lepidoptera: Noctuidae)

B. J. Ford J. R. Strayer
J. Reid G. L. Godfrey

Biological Notes No. 92

ILLINOIS NATURAL HISTORY SURVEY
Urbana, Illinois—February, 1975

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B. J. Ford, J. R. Strayer, J. Reid, and G. L. Godfrey

Anticarsia gemmatalis Hübner (1816) (Lepidoptera, Noctuidae) is an insect that has become a major concern to persons involved in the production of soybeans (*Glycine max* (L.) Merrill) in the Western Hemisphere. The larva of this species is commonly called the velvetbean caterpillar by researchers in the U.S.A. because it so seriously defoliated the velvetbean (*Stizolobium deeringianum* Bort) in the early 1900's (Chittenden 1905). Velvetbean caterpillar is now the common name for *A. gemmatalis* accepted by the Entomological Society of America.[1] Agricultural researchers in Mexico use a close Spanish equivalent for the common name, *gusano terciopelo*,[2] and Brazilian entomologists frequently refer to the species as *lagarta da soja*.

Until recently, the specific name was erroneously spelled "*gemmatilis*" by many authors. The error apparently traces back to Smith's (1893) misspelling. There are several synonyms in the literature partly because the maculation and coloration of the adults are extremely variable. Persons interested in the synonyms should consult Druce (1900) and Schaus (1940).

A. gemmatalis is primarily a foliage feeder on the Leguminosae. Guyton (1940) and English (1946) both described outbreaks of the caterpillars damaging peanuts (*Arachis hypogaea* L.) in Alabama. For Puerto Rico, Wolcott (1923, 1933, 1936, 1948, 1955) referred to the association of *A. gemmatalis* with soybean, peanut, alfalfa (*Medicago sativa* L.), sword bean (*Canavalia gladiata* DC.), bush bean (*Phaseolus vulgaris* var. *humilis* Alef.), lima bean (*P. limensis* Macf.), cowpea (*Vigna sinensis* Savi), and the gallito tree or Australian cork-wood tree (*Agati grandiflora* Desv.). Telford & Childers (1947) studied *A. gemmatalis* in relation to tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.) and kudzu (*P. lobata* (Willd.) Ohwi). Hinds & Osterberger (1931) reported cotton (*Gossypium*) as a host, but this seems to be the only nonleguminous host recorded for *A. gemmatalis* in the United States. Wheat (*Triticum*) was reported to be damaged by the species in Peru (Wille 1939).

Because the acreage and economic value of soybeans has increased substantially in subtropical and tropical areas during the last decade, it is not surprising that the species is now recognized as a major soybean pest. Outbreaks of the species on soybeans extend beyond the subtropics as far north as Maryland, Delaware, and Tennessee, U.S.A. These records were obtained from the U.S. Department of Agriculture Cooperative Economic Insect Report, Volumes 1–23 for 1951–1973. Soybean defoliation caused by *A. gemmatalis* in the U.S.A. is most serious in the southeastern and Gulf Coast states. The velvetbean caterpillar was first reported as a soybean pest in Florida and South Carolina by Nickels (1926). He estimated that in 1925 losses in South Carolina exceeded $500,000. Douglas (1930) reported the same insect defoliating soybeans in Texas. Hinds & Osterberger (1931) reported the velvetbean caterpillar as a pest in Louisiana, but did not believe it to be a limiting factor in soybean production. Strayer (1973) determined that soybean defoliation by *A. gemmatalis* was limiting production in Florida and reported the estimated cost of control was $1.2 million yearly from 1970 to 1973.

A detailed life history of *A. gemmatalis* was published by Watson (1916). Greene, et al. (1973) have further observed feeding of the caterpillar, and mating and oviposition of the moths. Eggs are most often laid singly. There are six to seven larval instars during the normal 3- to 4-week developmental period. The larva consumes 98 percent of its total food during the third through the last stage.

A. gemmatalis is regarded as a tropical to subtropical species. Apparently it does not overwinter in temperate regions. It is presently believed that the species survives winter no farther north than central Florida in the U.S.A. except during very mild winters and that economic outbreaks of the pest are primarily limited to Florida and neighboring states in late summer. However, as stated above, areas farther north have experienced outbreaks. Moths have been reported as far north in North America as Ontario, Canada (Watson 1916) and Wisconsin (Smith 1893). The

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[1] Entomological Society of America, Committee on Common Names of Insects. 1970. C. C. Blickenstaff, chairman. Common names of insects approved by the Entomological Society of America. [Published by the Entomological Society of America.] 36 p.

[2] Peña-M, R., and J. A. Sifuentes. 1972. Lista de nombres científicos y comunes de plagas agrícolas en México, 1972. Agricultura Técnica en México 3 : 132–144.

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western distributional limits in North America are not clearly documented. According to Pacheco (1970), velvetbean caterpillars occur in Valle del Yaqui, Sonora, Mexico. Dr. J. G. Franclemont, Cornell University, collected the moths of *A. gemmatalis* in Madera Canyon, Santa Rita Mountains in southern Arizona (personal communication to G. L. Godfrey). The species is widespread in South America and the West Indies. There are soybean association records as far south as the Argentine provinces of Corrientes and Misiones (Rizzo 1972), Cordoba, and Tucuman, with occasional records near the city of Buenos Aires (Rizzo, personal communication to G. L. Godfrey).

This bibliography on *A. gemmatalis* is the fourth[3] in a series contributing to the knowledge of the biology and control of arthropods on soybeans to assist in improved protection and production of this crop. The philosophy and scope of this bibliography is similar to that in the preceding bibliographies of the series. The references are not solely restricted to *A. gemmatalis* on soybeans. Many of the listed references pertain to the occurrence of *A. gemmatalis* on other leguminous crops, and to control measures, laboratory investigations, and systematics.

The titles in the present list were obtained primarily from standard reference sources and cross references. The literature search was concluded on December 31, 1973. The bibliography is as complete as possible with no deliberate screening except as noted below. References to reports in the USDA *Cooperative Economic Insect Report*, USDA *Insect Pest Survey Bulletin*, and *Canadian Insect Pest Review* were not included because their indexes are very complete. Interested researchers are urged to consult them for additional information. A few references have not been specifically searched, due to the inability of the authors to locate them. They are designated with the symbol #.

The references are listed alphabetically by author, numbered consecutively, and tabulated by subject and period of publication (see reference table following the numbered entries), a decade being the smallest period considered. A reference can appear more than once in the subject index. This procedure was adopted to make cross referencing for the index as complete as possible.

Title abbreviations of the periodicals cited in this publication are listed along with spelled-out titles at the end of the paper.

SIRIC (Soybean Insect Research and Information Center, Illinois Natural History Survey and University of Illinois at Urbana-Champaign) has developed a series of computer programs which make possible more detailed searches of the literature according to subject matter. All citations in this bibliography are stored on tape, and can be retrieved through a series of key words which define categories considerably more refined than those listed in the table which follows the numbered references. The computerized information system greatly increases the usefulness of the printed bibliographies, and the two together are an important part of the effort of the Illinois Soybean Entomology Team to search out, compile, and organize for ready access the ever-increasing information on soybean entomology for the benefit of all professionals working in this area.

We thank Dr. John G. Franclemont, Department of Entomology, Cornell University, for his advice and consultations that facilitated the completion of this bibliography. The final editing by O. F. Glissendorf and the cover design by Lloyd LeMere are much appreciated. Joe Ann Auble and Raymond Kotek contributed greatly by typing the manuscript.

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[3] Nichols, M. P., and M. Kogan. 1972. The literature of arthropods associated with soybeans. I. A bibliography of the Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae). Ill. Natur. Hist. Surv. Biol. Notes 77. 20 p.

DeWitt, N. B., and G. L. Godfrey. 1972. The literature of arthropods associated with soybeans. II. A bibliography of the southern green stink bug, *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae). Ill. Natur. Hist. Surv. Biol. Notes 78. 23 p.

Nichols, M. P., M. Kogan, and G. P. Waldbauer. 1974. The literature of arthropods associated with soybeans. III. A bibliography of the bean leaf beetles, *Cerotoma trifurcata* (Forster) and *C. ruficornis* (Olivier) (Coleoptera: Chrysomelidae). Ill. Natur. Hist. Surv. Biol. Notes 85. 16 p.

BIBLIOGRAPHY

1. ANONYMOUS. 1911/1912. Provision crops. Monserrat Bot. Sta. Rep. 1911/1912:8-14. illus.
2. ———. 1911/1912. Work connected with insect and fungus pests and their control. Monserrat Bot. Sta. Rep. 1911/1912:16.
3. ———. 1915. Pea and bean weevils. Agr. News (Barbados) 14(340):154. illus.
4. ———. 1917. Insect pests in the West Indies in 1916. Agr. News (Barbados) 16(392):138-139.
5. ———. 1927. Factors determining northern limits of *Anticarsia gemmatilis*. Fla. Entomol. 11(1):10-12.
6. ———. 1928. The velvet bean caterpillar, a peanut pest in the Everglades. Fla. Entomol. 12(3):39-40.
7. ———. 1929. Caterpillars damaging soy bean fields in Louisiana. Bur. Farmer 5(1):21.
8. ———. 1946. The control of velvetbean caterpillar. Ga. Coastal Plain Exp. Sta. Mimeo. Pap. 47. 2 p.
9. ———. 1947. Root crops and legumes in the Caribbean. Caribbean Res. Coun. Crop Inq. Ser. 4. 128 p. illus. refs. maps.
10. ———. 1952. Beans have pests like other crops. Soybean Dig. 12(10):26.
11. ———. 1953. You can control all known pests — by starting in time. Soybean Dig. 13(9):10-11. illus. refs.

12. ————. 1955. Control soybean insects. Va. Polytech. Inst. Agr. Ext. Serv. Circ. 648. 4 p. illus.

#13. ————. 1956. Lagarta da soja. [Soybean caterpillar.] Agr. Pecuar. 389:56.

14. ————. 1957. Insect pests of soybeans and their control. Soybean Dig. 17(10):16-18, 20. illus. refs.

15. ————. 1960. Control of insect pests. Soybean Dig. 20(8):14-16. illus.

16. ————. 1960. These are some pests that damage soybeans. Soybean Dig. 20(8):16-19. illus. refs.

17. ————. 1961. Corn earworm was important pest in 1960. Soybean Dig. 21(7):16. illus. maps.

18. Allen, G. E., G. L. Greene, and W. H. Whitcomb. 1971. An epizootic of *Spicaria rileyi* on the velvetbean caterpillar, *Anticarsia gemmatalis*, in Florida. Fla. Entomol. 54(2):189-191. illus. refs.

19. Allen, W. A., M. L. Bobb, J. M. Grayson, J. E. Roberts, Sr., W. H. Robinson, and J. A. Weidhaas. 1972. 1972 Virginia insect control guide. Va. Polytech. Inst. Ext. Div. Contr. Ser. 141. 118 p. illus. maps.

20. Annand, P. N. 1944/1945. Cereal and forage crop pests. U.S. Dep. Agr. Rep. Chf. Bur. Entomol. Plant Quar. 1945: 31-32.

21. ————. 1946/1947. Surveys help reduce losses from velvetbean caterpillar. U.S. Dep. Agr. Rep. Chf. Bur. Entomol. Plant Quar. 1947:32-33.

22. Arant, F. S. 1939. The relative efficiency of rotenone containing insecticides in the control of vegetable insects. Ala. Agr. Exp. Sta. Annu. Rep. 50:39-41. illus.

23. ————. 1942. Relative effectiveness of several rotenone-containing insecticides against various insects. J. Econ. Entomol. 35(6):873-878. illus. refs.

24. ————. 1945/1946. Velvetbean caterpillar and other peanut insects. Ala. Agr. Exp. Sta. Annu. Rep. 56/57:34-35.

25. ————. 1947/1948. Control of peanut insects. Ala. Agr. Exp. Sta. Annu. Rep. 58/59:43-44.

26. ————. 1948. Preliminary field tests with new insecticides for control of velvetbean caterpillar. J. Econ. Entomol. 41(5):803. illus. refs.

27. ————. 1948. Status of velvetbean caterpillar control in Alabama. J. Econ. Entomol. 41(1):26-30. illus. refs.

28. ————. 1951. Insect pests. *In*: The peanut — the unpredictable legume. A symposium. The National Fertilizer Association, Washington, D.C. p. 210-261. illus. refs.

29. Ballou, H. A. 1912. Insect pests of the Lesser Antilles. West Indies Imp. Dep. Agr. Pamph. Ser. 71. 210 p. illus.

30. ————. 1913. Notes on insect pests in Antigua. Bull. Entomol. Res. 4(1): 61-65. illus.

31. ————. 1916. Report on the prevalence of some pests and diseases in the West Indies during 1915. West Indian Bull. 16(1):1-30. illus.

32. Barber, G. W. 1936. Efficiency of *Trichogramma minutum* Riley in relation to population density of its host. J. Econ. Entomol. 29(3):631.

33. Barnes, W., and J. McDunnough. 1917. Check list of the Lepidoptera of Boreal America. Herald Press, Decatur, Ill. 392 p.

34. Barnhart, F. 1954. Soybean insects and their control. *In*: Soybeans. Floyd Barnhart, Caruthersville, Mo. p. 171-196. illus. refs.

35. Barss, H. P., and F. V. Rand. 1937. Plant pests and diseases. *In*: Report on the agricultural experiment stations, 1937. U.S. Dep. Agr. Off. Exp. Stas. Rep. 1937:62-102.

36. Bastos Cruz, B. P., M. Barreto Figueiredo, and E. Almeida. 1962. Principais doenças e pragas do amedoim no Estado de São Paulo. [Principal diseases and pests of groundnut in the state of São Paulo.] Biológico 28(7):189-195. illus.

37. Baver, L. D. 1945/1946. Soybean caterpillars stopped by DDT and benzene hexachloride dusts. N. C. Agr. Exp. Sta. Annu. Rep. 69:55-56.

38. Beattie, J. H., F. W. Poos, and B. B. Higgins. 1954. Growing peanuts. U.S. Dep. Agr. Farmers Bull. 2063. 54 p. illus. maps.

39. Begum, A., and W. G. Eden. 1963. When to treat soybeans for worm control. Highlights Agr. Res. 10(2):6. illus.

40. ————, and ————. 1965. Influence of defoliation on yield and quality of soybeans. J. Econ. Entomol. 58(3):591-592. illus. refs.

41. Biezanko, C. M. 1958. Algumas noções sobre a soja e seu cultivo. Utilidades da soja. [Some notions about soybeans and their cultivation. Usefulness of soybeans.] Gráfica Artex Ltda., Pelotas, Brasil. 24 p. refs.

#42. ————, and A. Ruffinelli. 1971. Fauna de Lepidoptera del Uruguay. X. Agaristidae, Noctuidae et Thyatiridae. [Fauna of Lepidoptera of Uruguay. X. Agaristidae, Noctuidae and Thyatiridae.] Uruguay Min. Agr. Gan. Centro Invest. Sanid. Veg. Publ. Tec. (Ser. Zool. Agr.) 2. 30 p.

43. ————, ————, and C. S. Carbonell. 1957. Lepidoptera del Uruguay. [Lepidoptera of Uruguay.] Rev. Fac. Agron. Univ. Repub. Uruguay 46. 152 p. refs.

#44. ————, ————, and ————. 1962. Lepidoptera del Uruguay. [Lepidoptera of Uruguay.] Rev. Fac. Agron. Univ. Repub. Uruguay 50. 166 p.

45. Bissell, T. L. 1939/1940. Miscellaneous insects. Ga. Exp. Sta. Annu. Rep. 52:62-64. illus.

46. ————, and C. H. Alden. 1945. Control of insect pests of peanuts in the field. Ga. Exp. Sta. Press. Bull. 546. 1 p.

47. Blackwell, C. P. 1926/1930. Report shows Oklahoma is pest center. Okla. Agr. Exp. Sta. Rep. 1926/1930:270-273.

48. Bledsoe, R. W., H. C. Harris, and F. Clark. 1945. The importance of peanuts left in the soil in the interpretation of increases in yield due to sulfur treatments. J. Amer. Soc. Agron. 37(9):689-695. illus. refs.

49. Blickenstaff, C. C., and J. L. Huggans. 1962. Soybean insects and related arthropods in Missouri. Mo. Agr. Exp. Sta. Res. Bull. 803. 51 p. illus. refs.

50. ————, and ————. 1974. Soybean insects and related arthropods in Missouri. Mo. Agr. Exp. Sta. Res. Bull. 803 (Rev.). 47 p. illus. refs.

51. Boyd, F. T. 1939/1940. Grain crop investigations. Fla. Agr. Exp. Sta. Annu. Rep. 1939/1940:182-183.

52. Briceño V., A. 1971. Contribucion al conocimiento de los insectos del mani (*Arachis hypogaea* L.) en el Zulia. [Contribution to the knowledge of the insects of the peanut (*Arachis hypogaea* L.) in Zulia.] (English summary.) Agron. Trop. (Maracay) 21(1):33-37. illus. refs.

53. Brimley, C. S. 1938. The insects of North Carolina.

North Carolina Department of Agriculture, Division of Entomology, Raleigh, N.C. 560 p.

54. Broersma, D. B. 1968. The soybean insect situation. Proc. N. Cent. Br. Entomol. Soc. Amer. 23(1):65-66.

55. Bruner, S. C. 1929/1930. Informe del Departamento de Entomologia y Fitopatologia, ejercicio de 1929 a 1930. [Report of the Department of Entomology and Phytopathology for 1929 to 1930.] Santiago de las Vegas Cuba Estac. Exp. Agron. Informe 1929/1930. 74 p. illus. refs.

56. ———, and J. B. Deschapelles. 1946. La palomilla del maiz o gusano de la yerba y medios de combatirla. [The fall armyworm and methods of combating it.] Santiago de las Vegas Cuba Estac. Exp. Agron. Circ. 84. 12 p. illus.

57. Burleigh, J. G. 1972. Population dynamics and biotic controls of the soybean looper in Louisiana. Environ. Entomol. 1(3):290-294. illus. refs.

58. Butler, A. G. 1878. On a small collection of Lepidoptera from Jamaica. Proc. Zool. Soc. London 1878:480-495. refs.

59. ———. 1879. On the Lepidoptera of the Amazons, collected by Dr. James W. H. Trail, during the years 1873 to 1875. Trans. Entomol. Soc. London 1879(1): 19-76. refs.

60. ———. 1895. Notes on the synonymy of noctuid moths. Entomologist 28(387):222-227. refs.

61. Campos Palomino, J. 1965. Investigaciones sobre el control biológico del "cogollero" del maíz, *Spodoptera frugiperda* (J. E. Smith) y otros noctuideos. [Investigations on the biological control of *Spodoptera frugiperda* and other noctuids.] (English summary.) Rev. Peru. Entomol. 8(1):126-131. illus. refs.

62. Chapin, J. B., and P. S. Callahan. 1967. A list of the Noctuidae (Lepidoptera, Insecta) collected in the vicinity of Baton Rouge, Louisiana. Proc. La. Acad. Sci. 30:39-48. illus. refs.

63. Chittenden, F. H. 1905. The caterpillar of *Anticarsia gemmatilis* injuring velvet bean. U.S. Dep. Agr. Bur. Entomol. Bull. 54:77-79. illus.

64. Costa, R. G. 1958. Alguns insetos e outros pequenos animais que danificam plantas cultivadas no Rio Grande do Sul. [Some insects and other small animals that damage cultivated plants in Rio Grande do Sul.] Secr. Est. Neg. Agr. Ind. Comerc. S.I.P.A. (Ser. A) 172. 296 p. illus. refs.

65. Cotton, R. T. 1918. Insectos que atacan las hortalizas en Puerto Rico. [Insects that attack vegetables in Puerto Rico.] Rev. Agr. P. R. 1(5):198-212. illus.

66. ———. 1918. Insects attacking vegetables in Porto Rico. J. Dep. Agr. P. R. 2(4):265-313. illus.

67. Creighton, C. S., T. L. McFadden, and E. R. Cuthbert. 1973. Supplementary data on phenylacetaldehyde: An attractant for Lepidoptera. J. Econ. Entomol. 66(1):114-115. illus. refs.

68. Crumb, S. E. 1956. The larvae of the Phalaenidae. U.S. Dep. Agr. Tech. Bull. 1135. 356 p. illus. refs.

69. Daane, A. 1931/1932. Forage crop investigations. Fla. Agr. Exp. Sta. Annu. Rep. 1931/1932:180-184.

70. Dash, J. S. 1914/1915. Report of the Assistant Superintendent of Agriculture on the entomological and mycological work carried out during the season under review. Barbados Dep. Agr. Rep. 1914/1915:38-44. illus.

71. ———. 1918/1919. Insectes. *In*: Rapport de l'Entomologiste et Pathologiste. [Insects. *In*: Report of the Entomologist and Pathologist.] Pointe-a-Pitre Guadeloupe Sta. Agr. Rapp. 1:29-32. illus.

72. Davidson, R. H., and L. M. Peairs. 1966. Insect pests of farm, garden, and orchard. John Wiley & Sons, Inc., New York. 6th Ed. 675 p. illus. refs.

73. Douglas, W. A. 1929. Caterpillar attacking soy beans, controlled by sodium fluosilicate. Rice J. 32(12):24.

74. ———. 1930. The velvet bean caterpillar as a pest of soy beans in southern Louisiana and Texas. J. Econ. Entomol. 23(4):684-690. refs.

75. Dozier, H. L. 1918. An annotated list of Gainesville, Florida, Coleoptera. Entomol. News 29(8,9,10):295-298, 331-335, 370-374.

76. Druce, H. 1884. On a collection of Heterocera from Dominica. Proc. Zool. Soc. London 1884:321-326. refs.

77. ———. 1900. Insecta. Lepidoptera-Heterocera. Biol. Cent.-Amer. 1:1-490. refs.

78. Dugas, A. L. 1945. Insecticidal tests on the control of the velvetbean caterpillar. Proc. Cotton States Br. Amer. Assoc. Econ. Entomol. 19:94-97. illus. refs.

79. ———, and E. J. Concienne. 1947. Control of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.) on soybeans in Louisiana. Proc. Assoc. S. Agr. Workers 44:123-124.

80. ———, and J. Gray. 1943/1944. Velvetbean caterpillar control on soybeans and peanuts. La. Agr. Exp. Sta. Annu. Rep. 1943/1944:83-86. illus.

81. ———, and C. E. Smith. 1944/1945. Velvetbean caterpillar on soybeans can be controlled with DDT or cryolite. La. Agr. Exp. Sta. Annu. Rep. 1944/1945: 59-60.

82. ———, ———, and E. J. Concienne. 1945/1946. Velvetbean caterpillar control on soybeans. La. Agr. Exp. Sta. Annu. Rep. 1945/1946:54-55.

83. ———, ———, and ———. 1946/1947. Velvetbean caterpillar. La. Agr. Exp. Sta. Annu. Rep. 1946/1947:55-56.

84. Dyar, H. G. 1902. A list of North American Lepidoptera and key to the literature of this order of insects. Bull. U.S. Nat. Mus. 52. 723 p. refs.

85. Eddy, C. O. 1939. Insects important in the production of sugarcane. Sugar Bull. 18:5-7.

86. ———. 1940. Cryolite as an insecticide. La. Agr. Exp. Sta. Bull. 323:3-5.

87. ———. 1941/1942. Cryolite necessary for effective soybean seed production. La. Agr. Exp. Sta. Annu. Rep. 1941/1942:74.

88. ———. 1942. Cryolite as an insecticide. No. 2. La. Agr. Exp. Sta. Bull. 350:9-11. illus.

89. ———. 1942. Cryolite controls many insects. Sugar Bull. 20:77-79. illus.

90. Ellisor, L. O. 1938. Control of the velvet bean caterpillar, *Anticarsia gemmatilis*, Hbn. in seed production. La. Agr. Exp. Sta. Bull. 298:8-9.

91. ———. 1942. Notes on the biology and control of the velvetbean caterpillar, *Anticarsia gemmatilis* Hbn. La. Agr. Exp. Sta. Bull. 350:17-23. refs.

92. ———, and C. R. Blair. 1940. Effect of temperature upon the toxicity of stomach poisons. J. Econ. Entomol. 33(5):760-762. illus. refs.

93. ———, and E. H. Floyd. 1938. Toxicity of several stomach-poison insecticides to four species of lepidopterous larvae. J. Econ. Entomol. 31(1):65-68. illus. refs.

94. ________, and ________. 1939. Further investigations on the control of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.). J. Econ. Entomol. 32(6):863-867. illus.

95. ________, J. H. Gayden, and E. H. Floyd. 1938. Experiments on the control of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.). J. Econ. Entomol. 31(6):739-742. illus. refs.

96. ________, and L. T. Graham. 1937. A recent pest of alfalfa. J. Econ. Entomol. 30(2):278-280. refs.

97. English, L. L. 1943/1944. Control of the velvetbean caterpillar on soybeans and peanuts. Ala. Agr. Exp. Sta. Annu. Rep. 54/55:28.

98. ________. 1946. Control of the peanut worm. Ala. Agr. Exp. Sta. Progr. Rep. Ser. 26. 3 p.

99. ________. 1946. The velvetbean caterpillar on peanuts: Control experiments. J. Econ. Entomol. 39(4): 531-533. illus. refs.

100. Etcheverry C., M. 1953. Identificaciones lepidopterologicas. [Lepidopterological identifications.] (English summary.) Rev. Chilena Entomol. 3:126-131. illus. refs.

101. Evans, W. 1968. Fighting the pests that eat soybean profits. Farm Quart. 23(2):102-105, 117-120. illus. refs.

102. Fagundes, A. C. 1962. Lagartas que atacam as fôlhas da soja. [Caterpillars that attack soybean leaves.] Correio Agro-Pecuar. (São Paulo) 2(4):55.

103. ________, and O. Baucke. 1962. Ensaio de campo com polvilhação visando o controle à "lagarta da soja" *Anticarsia gemmatilis* (Hübn., 1818) Lepidoptera-Noctuidae [Field experiment in an attempt at control of soybean caterpillar *Anticarsia gammatilis* Lepidoptera-Noctuidae through spraying.] Rev. Fac. Agron. Vet. Univ. Rio Grande do Sul 5(2):95-98. illus.

104. Falter, J. 1969. Soybean insect control. N. C. State Univ. Agr. Ext. Serv. Insect Notes, Grains & Soybeans Note 1. 6 p. illus.

105. Fawcett, H. S. 1948. Biological control of citrus insects by parasitic fungi and bacteria. *In*: L. D. Batchelor and H. J. Webber, *Eds.* The citrus industry. Volume II. Production of the crop. University of California Press, Berkeley. p. 627-664. illus. refs.

106. Fennah, R. G. 1945. Preliminary tests with DDT against insect pests of food-crops in the Lesser Antilles. Trop. Agr. (Trinidad) 22(12):222-226. illus.

107. Ferreira, E. 1970. Pragas da soja no Rio Grande do sul. [Pests of soybeans in Rio Grande do Sul.] Presented at No. I Simpósio Brasileiro de Soja. 11 p. illus. refs.

108. Forbes, W. T. M. 1914. A table of the genera of Noctuidae of northeastern North America. J. N. Y. Entomol. Soc. 22(1):1-33. illus.

109. ________. 1954. Lepidoptera of New York and neighboring states. Noctuidae. Part III. Cornell Univ. Agr. Exp. Sta. Mem. 329. 433 p. illus.

110. French, J. C., and M. P. Nolan, Jr. 1971. Soybean insects and their control. Univ. Ga. Coop. Ext. Serv. Leafl. 29 (Rev.). [2 p.] illus.

111. Frost, S. W. 1964. Insects taken in light traps at the Archbold Biological Station, Highlands County, Florida. Fla. Entomol. 47(2):129-161. refs.

112. Gallo, D., and C. H. W. Flechtmann. 1962. As mais importantes pragas das grandes culturas. [The most important pests of the great crops.] Bol. Didatico Esc. Super. Agr. "Luiz de Queiroz" Univ. São Paulo 3:1-144.

113. ________, O. Nakano, F. M. Wiendl, S. Silveira Neto, and R. P. L. Carvalho. 1970. Manual de entomologia. [Manual of entomology.] Editora Agronomica Ceres, São Paulo, Brasil. 858 p. illus. refs.

114. Genung, W. G., and V. E. Green, Jr. 1962. Insects attacking soybeans with emphasis on varietal susceptibility. Proc. Soil Crop Sci. Soc. Fla. 22:138-142. refs.

115. González, A. de J. 1932. Cultivo y utilizacion de la soya como forraje. [Cultivation and utilization of soybeans as forage.] Rev. Agr. Comerc. Trabajo (Cuba) 14(3):5-42. illus. refs.

116. Greene, G. L., J. C. Reid, V. N. Blount, and T. C. Riddle. 1973. Mating and oviposition behavior of the velvetbean caterpillar in soybeans. Environ. Entomol. 2(6):1113-1115. illus. refs.

117. Grossbeck, J. A. 1917. Insects of Florida. IV. Lepidoptera. Bull. Amer. Mus. Natur. Hist. 37:1-147.

118. Grote, A. R. 1874. List of the Noctuidae of North America. Bull. Buffalo Soc. Natur. Sci. 2:1-77. refs.

119. ________. 1876. Check list of the Noctuidae of America, north of Mexico. Part 2. Buffalo Freie Press, Buffalo, N.Y. p. 29-50.

120. ________. 1879. Notes on Noctuidae. Can. Entomol. 11(9):179-180.

121. ________. 1880. North American Noctuidae in the Zutraege. Can. Entomol. 12(5):84-88.

122. ________. 1880. Variability of *Anticarsia*. N. Amer. Entomol. 1(12):103.

123. ________. 1882. New check list of North American moths. A. R. Grote, New York. 73 p.

124. Guenée, M. A. 1852. Histoire naturelle des insectes. Species général des Lépidoptères. Tome VII. Noctuélites. Tome III. [Natural history of insects. General species of Lepidoptera. Tome VII. Noctuidae. Tome III.] Librairie Encyclopédique de Roret, Paris. 442 p. refs.

125. Guido, A. S., and A. Ruffinelli. 1956. Primer catalogo de los parasitos y predatores encontrados en el Uruguay. [First catalog of the parasites and predators found in Uruguay.] Proc. 10th Int. Congr. Entomol. (Montreal) 4:913-924. refs.

126. Gundlach, J. 1881. Contribucion á la entomologia Cubana. [Contribution to Cuban entomology.] Imprenta de G. Montiel, Habana. 445 p. refs.

127. ________. 1891. Apuntes para la fauna Puerto-Riqueña. [Notes on the Puerto Rican fauna.] An. Soc. Espan. Hist. Natur. 20:109-207. refs.

128. Guyton, F. E. 1940. An outbreak of the velvetbean caterpillar in Alabama with data on control. J. Econ. Entomol. 33(4):635-639. illus. refs. maps.

129. Gyrisco, G. G. 1958. Forage insects and their control. Annu. Rev. Entomol. 3:421-448. refs.

130. Hambleton, E. J. 1935. Alguns dados sobre Lepidopteros Brasileiros do Estado de Minas Geraes. [Some information on the Brazilian Lepidoptera of the state of Minas Geraes.] Rev. Entomol. (Rio de Janeiro) 5(1):1-7.

131. ________, and W. T. M. Forbes. 1935. Uma lista de Lepidoptera (Heterocera) do Estado de Minas Geraes. [A list of Lepidoptera (Heterocera) of the state of Minas Geraes.] (English summary) Arch. Inst. Biol. (São Paulo) 6:213-256.

132. Harris, H. C., W. B. Tisdale, and A. N. Tissot. 1946.

Importance of experimental technique in fertilizer, dusting and calcium experiments with Florida runner peanuts. Soil Sci. Soc. Amer. Proc. 11:413-416. illus. refs.

133. Hayward, K. J. 1927. Miscellaneous notes from Argentina. IX. Entomol. Rec. J. Var. 39(11):157-159.

134. ———. 1940. Departamento de Entomología. [Department of Entomology.] Rev. Ind. Agr. Tucuman 31(1-3):50-58. illus.

135. ———. 1942. Primera lista de insectos Tucumanos perjudiciales. [First list of harmful Tucuman insects.] Tucuman Estac. Exp. Agr. Publ. Misc. 1. 110 p. refs.

#136. ———. 1969. Datos para el estudio de la ontogenia de Lepidópteros Argentinos. [Datum for the study of the ontogeny of Argentinean Lepidoptera.] Fdn. M. Lillo Univ. Nac. Tucuman Misc. 31. 142 p.

#137. Herrich-Schäffer, G. A. W. 1864-1871. Die Schmetterlinge der Insel Cuba, nach naturlichen Exemplaren und Notizen des Herrn Dr. Gundlach in Habana zugesammengestellt von Dr. Herrich-Schäffer. [The Lepidoptera of the island of Cuba, according to the natural examples and notes of Herrn Dr. Gundlach in Havana compiled by Dr. Herrich-Schäffer.] CorrespBl. Zool.-Miner. Ver. Regensburg.

138. Hinds, W. E. 1930. The occurrence of *Anticarsia gemmatilis* as a soybean pest in Louisiana in 1929. J. Econ. Entomol. 23(4):711-714. illus.

139. ———. 1930. The occurrence of *Anticarsia gemmatilis* as a soy bean pest in Louisiana in 1929. Proc. Assoc. S. Agr. Workers 31:422-433.

140. ———. 1931. A new economic species attacking soybean hay in Louisiana (*Herculia psammioxantha* Dyar). J. Econ. Entomol. 24(4):833-835. illus.

141. ———. 1933. Trichogramma helping in control of soybean caterpillars. Sugar Bull. 11(23):3.

142. ———, and B. A. Osterberger. 1931. The soybean caterpillar in Louisiana. J. Econ. Entomol. 24(6):1168-1173. illus.

143. Hinson, K. 1967. Soybeans in Florida. Fla. Agr. Exp. Sta. Bull. 716. 121 p. illus. refs.

144. Holland, W. J. 1903. The moth book. Doubleday, Page & Company, New York. 479 p. illus. refs.

145. Howland, J. E. 1946. Record peanut crop saved from peanut worm. Better Homes Gard. 25(4):136.

146. Hubner, J. 1816. Verzeichniss bekannter Schmetterlinge. [Catalog of the known Lepidoptera.] Augsburg. 431 p. refs.

147. ———. 1818. Zuträge sur Sammlung exotischer Schmetterlinge, bestehend in Bekundigung einzelner Fliegmuster neuer oder rarer nichteuropäischer Gattungen. [Supplement to the collection of exotic Lepidoptera. . . .] Augsburg. 172 color plates.

148. Hughes, K. M. 1957. An annotated list and bibliography of insects reported to have virus diseases. Hilgardia 26(14):597-629. refs.

149. Jenkins, J. M. 1930. Entomological investigations. *In:* Report of the Rice Experiment Station for the years 1928–1929. La. Agr. Exp. Sta. Bull. 205:11-12.

150. Jordan, C. R. 1967. Soybean insects and their control. Univ. Ga. Coop. Ext. Serv. Leafl. 29 (Rev.). [2 p.] illus.

151. Kimball, C. P. 1965. Arthropods of Florida and neighboring land areas. Volume 1. Lepidoptera of Florida. Division of Plant Industry, State of Florida Department of Agriculture, Gainesville. 363 p. illus. refs.

152. King, G. H. 1947. Entomology. *In:* Twenty-seventh annual report, Georgia Coastal Plain Experiment Station, 1946–1947. Ga. Coastal Plain Exp. Sta. Bull. 44:42-45.

153. Kulash, W. M. 1947. Benzene hexachloride, DDT, and *Ryanex* to control soybean caterpillars. J. Econ. Entomol. 40(6):927-928. illus. refs.

154. Laster, M. L. 1962. Insects affecting soybeans in the South. Soybean Dig. 22(9):14-16. illus.

155. Ledbetter, R. J., and M. H. Bass. 1971. Soybean insects and their control. Auburn Univ. Coop. Ext. Serv. Circ. E-3. 7 p. illus.

156. Leonard, M. D., *Ed.* 1926. A list of the insects of New York with a list of the spiders and certain other allied groups. Cornell Univ. Agr. Exp. Sta. Mem. 101. 1,121 p.

157. Leuck, D. B., R. O. Hammons, L. W. Morgan, and J. E. Harvey. 1967. Insect preference for peanut varieties. J. Econ. Entomol. 60(6):1546-1549. illus. refs.

158. ———, and J. L. Skinner. 1971. Resistance in peanut foliage influencing fall armyworm control. J. Econ. Entomol. 64(1):148-150. illus. refs.

159. Lima, A. M. da C. 1936. Terceiro catalogo dos insetos que vivem nas plantas do Brasil. [Third catalog of insects that live on plants of Brazil.] Ministerio da Agricultura, Departamento Nacional da Producção Vegetal, Escola Nacional de Agronomia, Rio de Janeiro. 460 p. refs.

160. ———. 1950. Insetos do Brasil. 6º. Tomo. Lepidópteros. 2ª. Parte. [Insects of Brazil. Volume 6. Lepidoptera. Part 2.] Escola Nacional de Agronomia, Rio de Janeiro, Serie didatica No. 8. 420 p. illus. refs.

161. Lincoln, C., and F. D. Miner. 1945. Insect pests of grain, hay, and pasture crops. Ark. Agr. Exp. Sta. Ext. Serv. Circ. 437. 19 p. illus.

162. Lobdell, R. N. 1930/1931. Insect pests and their control. Fla. Agr. Exp. Sta. Annu. Rep. 45:149-152. illus.

163. ———. 1933/1934. Insect pests and their control. Fla. Agr. Exp. Sta. Annu. Rep. 1933/1934:93-94.

164. ———. 1934/1935. Insect pests and their control. Fla. Agr. Exp. Sta. Annu. Rep. 1934/1935:109-112. illus.

165. Luckmann, W. H. 1971. The insect pests of soyabeans. World Farming 13(5):18-19, 22. illus.

#166. Ludwig, J. M. 1957. Lagarta da soja. [Soybean caterpillar.] Agrotecnia (Porto Alegre) 1(3):29-33.

167. Lyle, C. 1944. Caterpillar may attack kudzu, soys. Miss. Farm Res. 7(9):1.

168. ———. 1945. Watch soybeans for caterpillars. Miss. Farm Res. 8(8):1.

169. McDunnough, J. 1938. Check list of the Lepidoptera of Canada and the United States of America. Part I. Macrolepidoptera. Mem. S. Calif. Acad. Sci. 1. 272 p.

170. Marcovitch, S., and W. W. Stanley. 1942. Fluorine compounds useful in the control of insects. Tenn. Agr. Exp. Sta. Bull. 182. 46 p. illus. refs.

171. Mariconi, F. A. M. 1958. Inseticidas e seu emprêgo no combate às pragas. [Insecticides and their use in the combat of pests.] Editora Agronomica "Ceres" Ltda., São Paulo. 531 p. illus. refs.

172. ———. 1963. Inseticidas e seu emprêgo no combate às pragas (com uma introdução sôbre o estudo dos insetos). [Insecticides and their use in the combat of pests (with an introduction on the study of insects).] Editora Agronomica "Ceres" Ltda., São Paulo. 2nd Ed. 607 p. illus. refs.

173. Martorell, L. F. 1945. A survey of the forest insects of Puerto Rico. J. Agr. Univ. P. R. 29(3,4): 69-608. illus. refs.

174. Menke, W. W. 1973. A computer simulation model: The velvetbean caterpillar in the soybean agroecosystem. Fla. Entomol. 56(2):92-102. illus. refs.

175. Mississippi Cooperative Extension Service. 1969. Entomology facts. Know your worms on soybeans. Miss. State Univ. Coop. Ext. Serv. Inform. Sheet 225. 2 p. illus.

176. Morse, W. J., and J. L. Cartter. 1969. Soybeans: Culture and varieties. U.S. Dep. Agr. Farmers Bull. 1520 (Rev.). 39 p. illus.

177. ———, ———, and L. F. Williams. 1949. Soybeans: Culture and varieties. U.S. Dep. Agr. Farmers Bull. 1520 (Rev.). 38 p. illus.

178. Moschler, H. B. 1880. Beiträge zur Schmetterlings-Fauna von Surinam. III. [Contributions to the lepidopterous fauna of Surinam. III.] Verh. K. K. Zool.-Bot. Ges. Wien 30:379-486. refs.

179. ———. 1886. Beiträge zur Schmetterlings-Fauna von Jamaica. [Contributions to the lepidopterous fauna of Jamaica.] Abh. Senckenberg. Naturforsch. Ges. 14(3):25-88. refs.

180. ———. 1889. Die Lepidopteren-Fauna der Insel Portorico. [The lepidopterous fauna of the island of Porto Rico.] Abh. Senckenberg. Naturforsch. Ges. 16(1):69-360. illus. refs.

181. Motsinger, R. E., J. L. Bagent, S. D. Hensley, N. L. Horn, and L. D. Newsom. 1967. Soybean diseases and insects of Louisiana. La. Coop. Ext. Serv. Publ. 1558. 24 p. illus.

182. Mullett, R. P. 1955. Insects and pests of field crops. Tenn. Agr. Exp. Sta. Ext. Serv. Publ. 360. 40 p. illus.

183. Myers, C. V. 1940. Insects inhabiting soybean fields. M. Sci. Thesis, University of Illinois. 69 p. illus. refs.

184. Neal, T. M., G. L. Greene, F. W. Mead, and W. H. Whitcomb. 1972. *Spanogonicus albofasciatus* (Hemiptera: Miridae): A predator in Florida soybeans. Fla. Entomol. 55(4):247-250. illus. refs.

185. ———, and W. H. Whitcomb. 1972. Odonata in the Florida soybean agroecosystem. Fla. Entomol. 55(2):107-114. refs.

186. Nettles, W. C. 1942. Cryolite controls soybean caterpillar. Clemson Agr. Coll. Ext. Serv. Inform. Card 65. 2 p. illus.

187. ———. 1958. Soybean insects and their control. Clemson Agr. Coll. Ext. Serv. Circ. 450. 10 p. illus.

188. ———, F. H. Smith, and C. A. Thomas. 1966. Soybean insects and diseases. How to control. Clemson Univ. Agr. Ext. Serv. Circ. 504. 21 p. illus.

189. ———, ———, and ———. 1967. Soybean insects and diseases. How to control. Clemson Univ. Agr. Ext. Serv. Circ. 504 (Rev.). 23 p. illus.

190. ———, ———, and ———. 1968. Soybean insects and diseases. How to control. Clemson Univ. Agr. Ext. Serv. Circ. 504 (Rev.). 25 p. illus.

191. ———, C. A. Thomas, and F. H. Smith. 1970. Soybean insects and diseases. How to control. Clemson Univ. Agr. Ext. Serv. Circ. 504 (Rev.). 25 p. illus.

192. Newell, W., and E. W. Berger. 1922. Insects injurious to the principal crops of the South. Fla. State Plant Bd. Quart. Bull. 6(4):97-116. refs.

193. Nickel, J. L. 1958. Agricultural insects of the Paraguayan Chaco. J. Econ. Entomol. 51(5):633-637. illus. refs.

194. Nickels, C. B. 1926. An important outbreak of insects infesting soy beans in lower South Carolina. J. Econ. Entomol. 19(4):614-618. illus.

195. Norman, A. G., *Ed.* 1963. The soybean: Genetics, breeding, physiology, nutrition, management. Academic Press, New York. 239 p. illus. refs.

196. Pacheco, F. 1970. Plagas del Valle del Yaqui. [Pests of the Yaqui Valley.] Mex. Inst. Nac. Invest. Agr. SAG. Circ. CIANO 53. 124 p. illus. refs.

197. Packard, C. M. 1945. Experiments with DDT for control of insects attacking cereal and forage crops in the field and in storage. U.S. Dep. Agr. Bur. Entomol. Plant Quar. E-640. 9 p.

198. ———. 1951. Insect pests of soybeans and their control. Soybean Dig. 11(4):14-18. illus.

199. Palmer, J. H., C. N. Nolan, C. L. Parks, F. H. Smith, M. C. McKenzie, and C. A. Thomas. 1972. Produce more high quality soybeans. Clemson Univ. Agr. Ext. Serv. Circ. 501 (Rev.). 7 p. illus. maps.

200. Parker, H. L. 1953. Miscellaneous notes on South American dipterous parasites. Boll. Lab. Entomol. Agr. "Filippo Silvestri" 12:45-73. illus. refs.

201. ———, P. A. Berry, and A. Silveira Guido. 1951. Host-parasite and parasite-host lists of insects reared in the South American Parasite Laboratory during the period 1940–1946. Rev. Assoc. Ing. Agron. 23(92):15-112.

202. Peairs, L. M. 1941. Insect pests of farm, garden, and orchard. John Wiley & Sons, Inc., New York. 4th Ed. 549 p. illus. refs.

203. ———, and R. H. Davidson. 1956. Insect pests of farm, garden, and orchard. John Wiley & Sons, Inc., New York. 5th Ed. 661 p. illus. refs.

204. Petch, T. 1925. Studies in entomogenous fungi. VII. *Spicaria*. Trans. Brit. Mycol. Soc. 10:183-189. illus. refs.

205. Peterson, A. 1948. Larvae of insects. Part I. Lepidoptera and plant infesting Hymenoptera. Alvah Peterson, Columbus, Ohio. 315 p. illus. refs.

206. ———. 1964. Egg types among moths of the Noctuidae (Lepidoptera). Fla. Entomol. 47(2):71-91. illus. refs.

207. Petty, H. B. 1967. How to control soybean insects. Farm Tech. 23(1):42A-47A. illus.

208. ———. 1967. How to control soybean insects. Soybean Dig. 27(4):42A-47A. illus.

209. Piper, C. V., and W. J. Morse. 1922. The velvet bean. U.S. Dep. Agr. Farmers Bull. 1276. 27 p. illus. maps.

210. ———, and ———. 1938. The velvetbean. U.S. Dep. Agr. Farmers Bull. 1276 (Rev.). 21 p. illus. maps.

211. ———, and ———. 1939. The velvet bean. Fla. Dep. Agr. Bull. (n.s.) 68:52-65. illus.

212. Plank, H. K. 1944. Insect pests of food crops. P. R. Fed. Exp. Sta. (Mayaguez) Rep. 1944:26-27.

213. Purswell, H. D. 1948. Seasonal occurrence of the velvetbean caterpillar in southeastern Alabama including data on life history and toxicity tests with

several organic insecticides. Ala. Polytech. Inst. Grad. Sch. Bull. 2:61-62.

214. Rego C. do V., J. G. Gomes, and G. B. Alvim. 1945. Doenças e pragas das plantas de horta. [Diseases and pests of garden plants.] Min. Agr. (Rio de Janeiro) S.I.A. 166. 230 p. illus. refs.

215. ———, ———, and ———. 1952. Doenças e pragas das plantas de horta. Fascículo V. Família dasleguminosas. [Diseases and pests of garden plants. Part V. Leguminosae.] Min. Agr. (Rio de Janeiro) S.I.A. 166. 2nd Ed. p. 5-42. illus.

216. Rizzo, H. F. E. 1971. Catálogo de Lepidópteros hallados en la Facultad de Agronomía y Veterinaria de Buenos Aires. [Catalog of the Lepidoptera found on the Faculty of Agronomy and Veterinary of Buenos Aires.] (English summary.) Univ. Buenos Aires Fac. Agron. Vet. Publ. Int. 2. 35 p. refs.

217. ———. 1972. Enemigos animales del cultivo de la soja. [Animal enemies of the cultivation of soybeans.] Rev. Inst. Bolsa Cereales 2851:1-6. illus. refs.

218. ———. 1972. Insectos y otros animales enemigos de la soja (*Glycine max* (L) Merril) en la Argentina. [Insects and other animal enemies of the soybean (*Glycine max* (L) Merril) in Argentina.] (English summary.) Rev. Fitotec. Latinoamer. 8(3):44-49. refs.

219. Roark, R. C. 1944. A review of the insecticidal uses of rotenone and rotenoids from derris, lonchocarpus (cube and timbo), tephrosia, and related plants. Part VII: Lepidoptera. U.S. Dep. Agr. Bur. Entomol. Plant Quar. E-625. 226 p. refs.

220. ———, and N.E. McIndoo. 1944. A digest of the literature on DDT through April 30, 1944. U.S. Dep. Agr. Bur. Entomol. Plant Quar. E-631. 53 p. refs.

221. Roberts, J. E., Sr., and J. C. Smith. 1972. Insect control recommendations. Control soybean insects. Va. Polytech. Inst. Ext. Div. Contr. Ser. 137. 4 p. illus.

222. Rowell, J. O. 1965. Control soybean insects. Va. Polytech. Inst. Agr. Ext. Serv. Circ. 648 (Rev.). [5 p.] illus.

223. ———, and G. M. Boush. 1963. Control soybean insects. Va. Polytech. Inst. Agr. Ext. Serv. Circ. 648 (Rev.). 4 p. illus.

224. Ruffin, W. A. 1947. Making the recommendation possible. Ext. Serv. Rev. 18(2):21.

225. Sanborn, C. E. 1930/1932. Study of many insect pests needed. Okla. Agr. Exp. Sta. Bien. Rep. 1930/1932:244-248.

226. Sanderson, E. D., and L. M. Peairs. 1931. Insect pests of farm, garden, and orchard. John Wiley & Sons, Inc., New York. 3rd Ed. 568 p. illus. refs.

227. Sarmento, A. A. 1958. Lagartas prejudiciais ãs nossas plantas cultivadas. [Caterpillars harmful to our cultivated plants.] Minas Gerais Brasil Dep. Prod. Veg. Bol. Agr. 7(11-12):13-26.

228. Schaus, W. 1940. Insects of Porto Rico and the Virgin Islands—Moths of the family Noctuidae. *In*: Scientific survey of Porto Rico and the Virgin Islands. New York Academy of Sciences, New York. Vol. XII, Part 2. p. 177-290. refs.

229. Schlottfeldt, C. S. 1944. Insetos encontrados em plantas cultivadas e comuns—Viçosa, Minas Gerais. [Insects found on cultivated and common plants—Viçosa, Minas Gerais.] Rev. Ceres 6(31):52-65.

230. ———. 1944. Insetos encontrados em plantas cultivadas e comuns—Viçosa, Minas Gerais. [Insects found on cultivated and common plants—Viçosa, Minas Gerais.] Rev. Ceres 6(32):108-126.

231. Scott, J. M. 1909/1910. The velvet bean. Fla. Dep. Agr. Bien. Rep. 11:174-195. illus.

232. ———. 1910. The velvet bean. Fla. Agr. Exp. Sta. Bull. 102:43-58. illus.

233. Scott, W. O., and S. R. Aldrich. 1970. Various soybean crop ailments. *In*: Modern soybean production. The Farm Quarterly, Cincinnati. p. 126-149. illus.

234. Sichmann, W. 1963. Principais pragas da cultura do amendoim. [Principal pests of the culture of peanuts.] Bol. Campo (Rio de Janeiro) 19(173):18-22. illus.

235. Silva, A. G., C. R. Gonçalves, D. M. Galvão, A. J. L. Gonçalves, J. Gomes, M. N. Silva, and L. Simoni. 1967–1968. Quarto catalogo dos insetos que vivem nas plantas do Brasil. Seus parasitos e predadores. [Fourth catalog of insects that live on plants in Brazil. Their parasites and predators.] Ministerio da Agricultura, Rio de Janeiro. Parte II, 1°. Tomo. 622 p. refs.

236. Silveira Neto, S., E. Berti Filho, and R. P. L. Carvalho. 1973. Flutuação populacional de algumas pragas da soja em Assis—SP. [Population fluctuation of some pests of soybeans in Assis.] (English summary.) Solo Cent. Acad. "Luiz de Queiroz" Univ. São Paulo 64(1):21-25. illus. refs.

237. Smith, C. F. 1946. Controlling soybean insects. Res. Farming (N. C. Agr. Exp. Sta.) 4(3):7, 9. illus.

238. Smith, J. B. 1882. A synopsis of the North American genera of the Noctuidae. Bull. Brooklyn Entomol. Soc. 5(1):3-6.

239. ———. 1891. List of the Lepidoptera of Boreal America. American Entomological Society. Philadelphia. 124 p.

240. ———. 1893. A catalogue, bibliographical and synonymical, of the species of moths of the lepidopterous superfamily Noctuidae, found in Boreal America with critical notes. Bull. U.S. Nat. Mus. 44. 424 p. refs.

241. ———. 1903. Check list of the Lepidoptera of Boreal America. American Entomological Society, Philadelphia. 136 p.

242. Smith, J. C. 1969. Soybean insect control by infurrow systemic and foliar spray treatments. Soybean Dig. 29(10):16-18. illus.

243. Spencer, A. P. 1915. The velvet bean caterpillar. Fla. Grower 12(13):19.

244. Steinhaus, E. A. 1957. New records of insect-virus diseases. Hilgardia 26(7):417-430. illus. refs.

245. Strayer, J. R. 1973. Economic threshold studies and sequential sampling for management of the velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, on soybeans. Ph.D. Diss., Clemson University. 87 p. illus. refs.

246. ———, and G. L. Greene. 1971. Soybean insect control. Fla. Coop. Ext. Serv. Plant Prot. Pointers Ext. Entomol. Mimeo. 36. 5 p. illus.

247. Stuckey, H. P. 1939/1940. Miscellaneous insects. Ga. Exp. Sta. Annu. Rep. 52:62-64. illus.

248. Suber, E. F., and J. C. French. 1973. Soybean insects and their control. Univ. Ga. Coop. Ext. Serv. Leafl. 29 (Rev.). [2 p.] illus.

249. Telford, E. A., and N. F. Childers. 1947. Tropical kudzu in Puerto Rico. P. R. Fed. Exp. Sta. (Mayaguez) Cir. 27. 30 p. illus. refs.

250. Tietz, H. M. 1952. The Lepidoptera of Pennsylvania.

The Pennsylvania State College School of Agriculture, State College, Penn. 194 p. illus. refs.

251. ———. 1972. An index to the described life histories, early stages and hosts of the Macrolepidoptera of the continental United States and Canada. The Allyn Museum of Entomology, Sarasota, Fla. Vol. I. 536 p. refs.

252. Tippins, H. H. 1963. Control of caterpillars on forage crops. Ga. Agr. Exp. Stas. Mimeo Ser. N. S. 160. 9 p. illus. refs.

253. Todd, J. W., and T. D. Canerday. 1972. Control of soybean-insect pests with certain systemic insecticides. J. Econ. Entomol. 65(2):501-504. illus. refs.

254. ———, N. A. Minton, and P. D. Dukes. 1972. Infestations of phytophagous insects on soybeans following applications of du Pont 1410 foliar sprays and other insecticides applied to the soil. J. Econ. Entomol. 65(1):295-296. illus. refs.

255. ———, and L. W. Morgan. 1972. Effects of hand defoliation on yield and seed weight of soybeans. J. Econ. Entomol. 65(2): 567-570. illus. refs.

256. ———, M. B. Parker, and T. P. Gaines. 1972. Populations of Mexican bean beetles in relation to leaf protein of modulating and non-modulating soybeans. J. Econ. Entomol. 65(3):729-731. illus. refs.

257. Townsend, C. H. T. 1916. Description of two new tachinids (Dip.). Entomol. News 27(5):217.

258. Tracy, S. M., and H. S. Coe. 1918. Velvet beans. U.S. Dep. Agr. Farmers Bull. 962. 39 p. illus. maps.

259. Trullinger, R. W., et al. 1945/1946. Insects as related to agriculture. U.S. Dep. Agr. Agr. Res. Serv. Rep. Stat. Agr. Exp. Stas. 1945/1946:104-117.

260. Tugwell, P., E. P. Rouse, and R. G. Thompson. 1973. Insects in soybeans and a weed host (*Desmodium* sp.). Ark. Agr. Exp. Sta. Rep. Ser. 214. 18 p. illus. refs.

261. Turnipseed, S. G. 1965. Leaf damage in soybeans—can it lower yields? Clemson Univ. Agr. Res. 12(1):8. illus.

262. ———. 1967. Systemic insecticides for control of soybean insects in South Carolina. J. Econ. Entomol. 60(4):1054-1056. illus. refs.

263. ———. 1972. Management of insect pests of soybeans. Proc. Tall Timbers Conf. Ecol. Anim. Contr. Habitat Manage. 4:189-203. illus. refs.

264. ———. 1972. Response of soybeans to foliage losses in South Carolina. J. Econ. Entomol. 65(1): 224-229. illus. refs.

265. ———, J. W. Todd, G. L. Greene, and M. H. Bass. 1974. Minimum rates of insecticides on soybeans: Mexican bean beetle, green cloverworm, corn earworm and velvetbean caterpillar. J. Econ. Entomol. 67(2):287-291. illus. refs.

266. USDA. 1952. Velvetbean caterpillar. U.S. Dep. Agr. Yearb. Agr. 1952:plate 69.

267. ———. 1953. The velvetbean caterpillar. How to control it. U.S. Dep. Agr. Leafl. 348. 4 p. illus.

268. ———. 1959. The velvetbean caterpillar. How to control it. U.S. Dep. Agr. Leafl. 348 (Rev.). 4 p. illus.

269. USDA Agricultural Research Service and Forest Service. 1967. Suggested guide for the use of insecticides to control insects affecting crops, livestock, households, stored products, forests, and forest products – 1967. U.S. Dep. Agr. Agr. Handb. 331. 273 p. illus.

270. ———. 1968. Suggested guide for the use of insecticides to control insects affecting crops, livestock, households, stored products, forests, and forest products – 1968. U.S. Dep. Agr. Agr. Handb. 331 (Rev.). 273 p. illus.

271. Vance, A. M. 1955. Pests that may attack your soybeans. Soybean Dig. 15(8):14-15. illus.

272. Van Dinther, J. B. M. 1956. Soybean insects. Entomol. Ber. (Amsterdam) 16(6):104-109. illus. refs.

#273. Vernett, F. de J. 1962. Soja—combate às ervas daninhas, contrôle de doenças e pragas. [Soybean—combat of noxious weeds, and control of diseases and pests.] FIR (São Paulo) 4(5):37-41.

274. Vilela, M. 1966. Resultados obtidos no primeiro ano de aplicação de *Malatol LVC* em algodão e soja. [Results obtained in the first year of applying *Malatol LVC* on cotton and soybean.] An. Reun. Fitosanit. Brasil 10:79-80. illus.

275. Vinson, E. B. 1950. Parathion, toxaphene and DDT residues on peanut hay with field data on the use of these chemicals against certain peanut insects. Ala. Polytech. Inst. Grad. Sch. Bull. 3:81-82.

276. Walker, F. 1856–1858. List of the specimens of lepidopterous insects in the collection of the British Museum. Parts IX–XV. Noctuidae. The British Museum, London. p. 1-1888. refs.

277. ———. 1869. Characters of undescribed Lepidoptera Heterocera. E. W. Janson, London. 112 p.

278. Walton, R. R., and C. F. Stiles. 1952. The control of caterpillars attacking soybeans. Okla. Agr. Exp. Sta. Mimeo. Circ. M-239. 2 p.

279. Waters, H. A., E. D. Witman, and D. M. DeLong. 1939. Basic copper arsenate—a new insecticide. II. Insecticide and phytotoxity studies. J. Econ. Entomol. 32(1):144-146.

280. Watson, J. R. 1911/1912. Insects of the year. Fla. Agr. Exp. Sta. Annu. Rep. 1911/1912:62-63.

281. ———. 1912/1913. Destructive insects of the year. Fla. Agr. Exp. Sta. Annu. Rep. 1912/1913:65-71. illus.

282. ———. 1913. Spraying for the velvet bean caterpillar. Fla. Agr. Exp. Sta. Press Bull. 216. 2 p.

283. ———. 1913. Spraying for the velvet bean caterpillar. Fla. Grower 10:8.

284. ———. 1913/1914. The use of sprays against the caterpillar of velvet beans. Fla. Agr. Exp. Sta. Annu. Rep. 1913/1914:50-52. illus.

285. ———. 1914/1915. The velvet bean caterpillar. (*Anticarsia gemmatilis.*). Fla. Agr. Exp. Sta. Annu. Rep. 1914/1915:49-64. illus.

286. ———. 1915. Another migratory moth (Lep.). Entomol. News 26(9):419-422.

287. ———. 1915/1916. Control of the velvet bean caterpillar. Fla. Dep. Agr. Bien. Rep. 14(2):183-193. illus.

288. ———. 1915/1916. Velvet bean caterpillar (*Anticarsia gemmatilis*). Fla. Agr. Exp. Sta. Annu. Rep. 1915/1916:51R.

289. ———. 1916. Control of the velvet bean caterpillar. Fla. Agr. Exp. Sta. Bull. 130:45-58. illus.

290. ———. 1916. Control of the velvet bean caterpillar. Fla. Dep. Agr. Quart. Bull. 26(3):69-80. illus.

291. ———. 1916. Life-history of the velvet-bean caterpillar (*Anticarsia gemmatilis* Hübner). J. Econ. Entomol. 9(6):521-528. illus. maps.

292. ———. 1916. The velvet bean caterpillar and its control. Fla. Grower 13(5):11-12. illus.

293. ———. 1916/1917. Velvet-bean caterpillar (*Anticarsia gemmatilis*). Fla. Agr. Exp. Sta. Annu. Rep. 1916/1917:52R-53R.

294. ———. 1917/1918. The velvet-bean caterpillar (*Anticarsia gemmatilis*). Fla. Agr. Exp. Sta. Annu. Rep. 1917/1918:56R.

295. ———. 1918. Method of controlling velvet bean caterpillars. Fla. Grower 18(12):15.

296. ———. 1918/1919. Velvet bean caterpillar (*Anticarsia gemmatilis*). Fla. Agr. Exp. Sta. Annu. Rep. 1918/1919:51R-53R. illus.

#297. ———. 1919/1920. The velvet bean caterpillar and the winter weather. Fla. Agr. Exp. Sta. Annu. Rep. 1919/1920:21R-23R.

298. ———. 1920/1921. The velvet-bean caterpillar. Fla. Agr. Exp. Sta. Annu. Rep. 1920/1921:30R-31R.

299. ———. 1921. The velvet bean caterpillar. Fla. Agr. Exp. Sta. Press Bull. 325. 2 p.

300. ———. 1921/1922. Farm crop insect work. Fla. Agr. Exp. Sta. Annu. Rep. 1921/1922:57R.

301. ———. 1922. Bunch velvet beans to control root-knot. Fla. Agr. Exp. Sta. Bull. 163:53-59. illus.

302. ———. 1922/1923. Insects of farm crops. Fla. Agr. Exp. Sta. Annu. Rep. 1922/1923:110R-111R.

303. ———. 1925/1926. The velvet bean caterpillar. (*Anticarsia gemmatilis*). Fla. Agr. Exp. Sta. Annu. Rep. 1925/1926:45R.

304. ———. 1928/1929. Life history studies and control of the velvet bean caterpillar. Fla. Agr. Exp. Sta. Annu. Rep. 1928/1929:53.

305. ———. 1929/1930. Velvet bean insects. Fla. Agr. Exp. Sta. Annu. Rep. 1929/1930:67.

306. ———. 1932. Further notes on the velvet bean caterpillar. Fla. Entomol. 16(2):24.

307. ———. 1932. Insects of the winter, 1931-32. Fla. Entomol. 15(4):71-73. illus.

308. ———. 1942. Insect conditions in Florida in 1941. Citrus Ind. 23(2):6, 14.

309. ———. 1943. Peanut insects and other enemies. Fla. Agr. Exp. Sta. Press Bull. 585. 4 p. illus.

310. ———. 1946. Control of summer crop insects. Fla. Grower 55[54](9):15, 18.

311. WHEELER, W. A. 1950. Forage and pasture crops. D. Van Nostrand Company, Inc., New York. 752 p. illus. refs.

312. WILLE, J. E. 1931/1932. Informe que presenta el Jefe de la Sección de Entomología, Dr. Johannes Wille, sobre la visita de inspección que ha practicado en el Valle de Tambo desde el 25 de noviembre al 7 de diciembre de 1931. [Report of the Head of the Section of Entomology, Dr. Johannes Wille, on a visit of inspection to the Tambo Valley, 25th November to 7th December 1931.] Mem. Soc. Nac. Agr. Lima 1931/1932:177-181.

313. ———. 1934. Der Zuckerrohrschädling *Anacentrinus saccharidis* Barber (Coleopt. Curcul.). Seine Massenvermehrung und die anderer Schädlinge in Peru in den Jahren 1930 bis 1931. (Beiträge zur Schädlingsfauna von Peru. VIII.). [The sugar-cane pest, *Anacentrinus saccharidis*. Its mass-increase and that of other pests in Peru in 1930 to 1931. (Contributions to the pest fauna of Peru. VIII.).] Der Tropenpflanzer 37(5-6):185-198, 233-252. illus. refs.

314. ———. 1939. Departamento de Entomología. Memoria del Jefe del Departamento. [Department of Entomology. Memoir of the Chief of the Department.] La Molina Estac. Exp. Agr. Mem. 12:177-210. illus.

315. ———. 1941. Servicio especializado de entomología. [Specialized service of entomology.] La Molina Estac. Exp. Agr. Mem. 14:189-231. illus.

316. ———. 1943. Entomologia agricola del Peru. [Agricultural entomology of Peru.] Ministerio de Agricultura (Imprenta Americana), Lima, Peru. 468 p. illus. refs.

317. ———, and G. GARCIA RADA. 1942. Los insectos y las enfermedades del lino. [Insects and diseases of flax.] La Molina Estac. Exp. Agr. Informe 54. 19 p. illus.

318. ———, A. PEREZ ALCAZAR, and G. JOHANSON G. 1947. Informe sobre los resultados obtenidos en la temporada de 1946–47 en el control de los insectos de la alfalfa por medio del insecticida DDT. [Report on the results obtained in the season of 1946-47 in the control of insects attacking alfalfa with the insecticide DDT.] La Molina Estac. Exp. Agr. Informe 66. 16 p. illus.

319. WILSON, C., and F. S. ARANT. 1949. Control of insects and diseases of peanuts. Ala. Agr. Exp. Sta. Leafl. 27. 4 p.

320. WILSON, R. N. 1916. The velvet bean caterpillar. J. Econ. Entomol. 9(6):570.

321. WOLCOTT, G. N. 1923. "Insectae Portoricensis." A preliminary annotated checklist of the insects of Porto Rico, with descriptions of some new species. J. Dep. Agr. P. R. 7(1):5-313. refs.

322. ———. 1933. An economic entomology of the West Indies. The Entomological Society of Puerto Rico, San Juan. 688 p. illus. refs.

323. ———. 1936. "Insectae Borinquenses." A revision of "'Insectae Portoricensis,' a preliminary annotated check-list of the insects of Porto Rico, with descriptions of some new species," and "First supplement to Insectae Portoricensis." J. Agr. Univ. P. R. 20(1):1-627. illus. refs.

324. ———. 1948. The insects of Puerto Rico. J. Agr. Univ. P. R. 32(1,2,3,4):1-975. illus. refs.

325. ———. 1955. Experiences with entomogenous fungi in Puerto Rico. P. R. Agr. Exp. Sta. Bull. 130. 19 p. illus. refs.

326. ———, and L. F. MARTORELL. 1940. Epidemics of fungus disease control insect pests in Puerto Rico. J. Econ. Entomol. 33(1):201-202. refs.

327. YOUNG, H. C. 1944. DDT against the white-fringed beetle and the velvet bean caterpillar. J. Econ. Entomol. 37(1):145-147. illus.

TABLE OF REFERENCES BY SUBJECT AND PERIOD OF PUBLICATION

YEAR / SUBJECT	1816–1899	1900–1909	1910's	1920's	1930's	1940's	1950's	1960's	1970's	SOYBEAN
AXONOMY	58,59,60,76, 118,119,120, 121,123,124, 126,127,146, 147,178,179, 180,238,239, 240,276,277	77,84, 144,241	33,108	321	131,159,169, 323	228	43,68,100, 109,250	151	216,251	131,151,159,216,228,250,251
STRIBUTION	118,127,178, 179,180,240, 276	77,84, 144	117,258,285, 286,287,289, 290,291	5,156	74,115,130, 211	173,228	43,68,109, 160,171,250, 272	62,172,195	218	5,74,115,130,160,171,172,195,218, 228,250,272
E HISTORY & BIOLOGY	122	231	117,232,285, 286,287,289, 290,291,292, 294,296	5,7,55, 73,133, 209,298, 299,302, 304	74,90,131, 138,142,149, 176,210,211, 247,306,307, 313	91,167,173,177, 183,186,202,205, 213,308	28,34,43, 171,182,187, 198,203,250, 266,267,268, 272	16,72,111, 143,172,188, 189,190,195, 206,234	67,113,116, 191,196,217, 218,236,251	5,7,16,28,34,72,73,74,90,91, 113,116,131,138,142,143,149,167, 171,172,176,177,182,183,186,187, 188,189,190,191,195,196,198,202, 203,205,217,218,234,236,247,250, 251,266,267,268,272
ECOLOGY									116,174,236, 245,260	116,174,236,245,260
RPHOLOGY & YSIOLOGY	122		291			205	28	206	67	28,205
CONOMIC ROLE DAMAGE		63,231	1,2,4,31,70, 232,243,258, 280,287,289, 290,320	6,7,47, 55,192, 194,209, 303	45,53,69,74, 85,96,138, 140,142,176, 210,211,225, 247,314	8,9,20,21,82, 134,167,177,183, 186,212,213,214, 224,315,316,317	11,28,34,41, 129,187,215, 311	17,36,39,40, 49,54,101, 143,154,157, 181,188,189, 190,234,261	50,52,107, 165,191,196, 217,245,255, 264	6,7,8,9,11,17,20,21,28,34, 39,40,41,45,47,49,50,53,54,69, 74,82,85,96,101,107,134,138,140, 142,143,154,165,167,176,177,181, 183,186,187,188,189,190,191,194, 196,212,214,215,217,225,234,245, 247,255,261,264,303,311
ST PLANTS, HOST LECTION, FEEDING EHAVIOR	277		117,284,285, 287,289,290, 291,292,293	6,194, 300,321	45,69,74,96, 130,138,139, 142,159,162, 176,226,247, 306,322,323	8,91,128,135, 161,167,168,173, 177,183,186,202, 205,228,229,230, 249,318,324	28,43,64,68, 160,171,182, 193,198,203, 227,250,266, 267,268,272, 311	72,114,143, 151,157,172, 234,235	216,251,256, 260	6,8,28,45,69,72,74,91,96,114, 128,130,135,138,139,142,143,151, 159,160,161,162,167,168,171,172, 176,177,182,183,186,194,198,202, 203,205,216,227,228,230,234,235, 247,250,251,256,260,266,267,268, 272,311,324
HEMICAL ONTROL		231	2,3,29,65, 66,70,232, 243,258,281, 282,283,284, 285,287,289, 290,292,293, 295	7,73, 194,209, 299,301, 304	22,74,85,90, 94,95,96, 115,138,139, 142,149,162, 163,164,176, 210,211,226, 279,312,322	8,9,23,24,25,26, 27,37,46,48,56, 78,79,80,81,82, 83,86,87,88,89, 91,97,98,99,106, 128,132,145,152, 153,161,167,168, 170,177,183,186, 197,202,213,219, 220,224,237,259, 309,310,318,319, 324,327	10,11,12,14, 28,34,38,64, 171,182,187, 198,203,227, 266,267,268, 271,275,278, 311	15,16,36,39, 40,72,103, 104,143,150, 154,172,175, 188,189,190, 207,208,222, 223,242,252, 262,269,270, 274	19,107,110, 113,155,165, 191,196,199, 217,221,233, 246,248,253, 254,263,265	7,8,9,10,11,12,14,15,16,19, 26,28,34,37,39,40,56,72,73,74, 78,79,80,81,82,83,85,86,87,88, 89,90,91,94,95,96,97,103,104, 107,110,113,115,128,138,139,142, 143,149,150,153,154,155,161,162, 165,167,168,171,172,175,176,177, 182,183,186,187,188,189,190,191, 194,196,197,198,199,202,203,207, 208,217,221,222,223,227,233,237, 242,246,248,253,254,259,262,263, 265,266,267,268,269,270,271,274, 275,278,279,309,311,324
OLOGICAL, LTURAL, & CHANICAL ONTROL		63	1,29,281, 282,283,284, 285,287,288, 289,290,292, 295,296,320	298,299, 302,304, 305	51,74,96, 141,162,226	91,105,161,173, 183,186,309,326	267,268,325	61,188,189, 190	158,165,185, 191,246,263	51,74,91,96,141,161,162,165,183, 185,186,188,189,190,191,246,263, 267,268,309
RASITES, EDATORS, DISEASES		231	30,71,75, 232,257,281, 282,283,284, 285,286,287, 288,289,290, 291,293,296, 320	6,194, 204,300	32,35,74,96, 115,138,139, 141,142	78,91,105,183, 186,212,308,309, 324,326	28,100,125, 148,200,201, 244,267,268, 272,325	61,143,235	18,57,107, 184,185,246, 263	6,18,28,32,57,74,78,91,96,107, 115,138,139,141,142,143,183,184, 185,186,194,212,235,246,263,267, 268,272,309,324
XICOLOGY					93	92				

PERIODICAL ABBREVIATIONS

Abh. Senckenberg. Naturforsch. Ges.—Abhandlungen der Senckenbergischen naturforschenden Gesellschaft.

Agr. News (Barbados)—The Agricultural News (Barbados).

Agr. Pecuar.—Agricultura e Pecuaria (Rio de Janeiro).

Agron. Trop. (Maracay)—Agronomia Tropical (Maracay).

Ala. Agr. Exp. Sta. Annu. Rep.—Alabama Agricultural Experiment Station Annual Report.

Ala. Agr. Exp. Sta. Leafl.—Alabama Agricultural Experiment Station Leaflet.

Ala. Agr. Exp. Sta. Progr. Rep. Ser.—Alabama Agricultural Experiment Station Progress Report Series.

Ala. Polytech. Inst. Grad. Sch. Bull.—Alabama Polytechnic Institute, Graduate School Bulletin.

An. Reun. Fitosanit. Brasil—Anais da Reuniao Fitosanitaristas do Brasil.

An. Soc. Espan. Hist. Natur.—Anales de la Sociedad Espanola de Historia Natural.

Annu. Rev. Entomol.—Annual Review of Entomology.

Arch. Inst. Biol. (São Paulo)—Archivos do Instituto Biologico (São Paulo).

Ark. Agr. Exp. Sta. Ext. Serv. Circ.—Arkansas Agricultural Experiment Station Extension Service Circular.

Ark. Agr. Exp. Sta. Rep. Ser.—Arkansas Agricultural Experiment Station Report Series.

Auburn Univ. Coop. Ext. Serv. Circ.—Auburn University Cooperative Extension Service Circular.

Barbados Dep. Agr. Rep.—Report on the Department of Agriculture, Barbados.

Better Homes Gard.—Better Homes and Gardens.

Biol. Cent.-Amer.—Biologia Centrali-Americana.

Bol. Campo (Rio de Janeiro)—Boletim do Campo (Rio de Janeiro).

Bol. Didatico Esc. Super. Agr."Luiz de Queiroz" Univ. São Paulo—Boletim Didatico, Escola Superior de Agricultura "Luiz de Queiroz" Universidade de São Paulo.

Boll. Lab. Entomol. Agr. "Filippo Silvestri"—Bollettino del Laboratorio di Entomologia Agraria "Filippo Silvestri."

Bull. Amer. Mus. Natur. Hist.—Bulletin of the American Museum of Natural History.

Bull. Brooklyn Entomol. Soc.—Bulletin of the Brooklyn Entomological Society.

Bull. Buffalo Soc. Natur. Sci.—Bulletin of the Buffalo Society of Natural Sciences.

Bull. Entomol. Res.—Bulletin of Entomological Research.

Bull. U.S. Nat. Mus.—Bulletin of the United States National Museum.

Bur. Farmer—Bureau Farmer (Louisiana Edition).

Can. Entomol.—Canadian Entomologist.

Caribbean Res. Coun., Crop Inq. Ser.—Caribbean Research Council, Crop Inquiry Series.

Citrus Ind.—Citrus Industry.

Clemson Agr. Coll. Ext. Serv. Circ.—Clemson Agricultural College Extension Service Circular.

Clemson Agr. Coll. Ext. Serv. Inform. Card—Clemson Agricultural College Extension Service Information Card.

Clemson Univ. Agr. Ext. Serv. Circ.—Clemson University Agricultural Extension Service Circular.

Clemson Univ. Agr. Res.—Clemson University Agricultural Research.

Cornell Univ. Agr. Exp. Sta. Mem.—Cornell University Agricultural Experiment Station Memoir.

Correio Agro-Pecuar. (São Paulo)—Correio Agro-Pecuario (São Paulo).

CorrespBl. Zool.-Miner. Ver. Regensburg—Correspondenz-Blatt des Zoologisch-Mineralogischen Vereins in Regensburg.

Entomol. Ber. (Amsterdam)—Entomologische Berichten (Amsterdam).

Entomol. News—Entomological News.

Entomol. Rec. J. Var.—The Entomologist's Record & Journal of Variation.

Environ. Entomol.—Environmental Entomology.

Ext. Serv. Rev.—Extension Service Review.

Farm Quart.—Farm Quarterly.

Farm Tech.—Farm Technology.

Fdn. M. Lillo Univ. Nac. Tucuman Misc.—Fundacion M. Lillo, Universidad Nacional de Tucuman, Argentina, Miscelanea.

FIR (São Paulo)—Fertilizantes, Inseticidas e Racoes (São Paulo).

Fla. Agr. Exp. Sta. Annu. Rep.—Florida Agricultural Experiment Station Annual Report.

Fla. Agr. Exp. Sta. Bull.—Florida Agricultural Experiment Station Bulletin.

Fla. Agr. Exp. Sta. Press Bull.—Florida Agricultural Experiment Station Press Bulletin.

Fla. Coop. Ext. Serv. Plant Prot. Pointers Ext. Entomol. Mimeo.—Florida Cooperative Extension Service, Plant Protection Pointers, Extension Entomology Mimeograph.

Fla. Dep. Agr. Bien. Rep.—Florida Department of Agriculture Biennial Report.

Fla. Dep. Agr. Bull. (n.s.)—Florida Department of Agriculture Bulletin, New Series.

Fla. Dep. Agr. Quart. Bull.—Florida Department of Agriculture Quarterly Bulletin.

Fla. Entomol.—Florida Entomologist.

Fla. Grower—The Florida Grower.

Fla. State Plant Bd. Quart. Bull.—Florida State Plant Board Quarterly Bulletin.

Ga. Agr. Exp. Stas. Mimeo Ser.—Georgia Agricultural Experiment Stations Mimeo Series.

Ga. Coastal Plain Exp. Sta. Bull.—Georgia Coastal Plain Experiment Station Bulletin.

Ga. Coastal Plain Exp. Sta. Mimeo. Pap.—Georgia Coastal Plain Experiment Station Mimeograph Paper.

Ga. Exp. Sta. Annu. Rep.—Georgia Experiment Station Annual Report.

Ga. Exp. Sta. Press Bull.—Georgia Experiment Station Press Bulletin.

Highlights Agr. Res.—Highlights of Agricultural Research.

J. Agr. Univ. P. R.—Journal of Agriculture of the University of Puerto Rico.

J. Amer. Soc. Agron.—Journal of the American Society of Agronomy.

J. Dep. Agr. P. R.—Journal of the Department of Agriculture of Porto Rico.

J. Econ. Entomol.—Journal of Economic Entomology.

J. N. Y. Entomol. Soc.—Journal of the New York Entomological Society.

La. Agr. Exp. Sta. Annu. Rep.—Louisiana Agricultural Experiment Station Annual Report.

La. Agr. Exp. Sta. Bull.—Louisiana Agricultural Experiment Station Bulletin.

La. Coop. Ext. Serv. Publ.—Louisiana Cooperative Extension Service Publication.

La Molina Estac. Exp. Agr. Informe—La Molina, Peru, Estacion Experimental Agricola Informe.

La Molina Estac. Exp. Agr. Mem.—La Molina, Peru, Estacion Experimental Agricola Memoria.

Mem. S. Calif. Acad. Sci.—Memoirs of the Southern California Academy of Sciences.

Mem. Soc. Nac. Agr. Lima—Memoria de la Sociedad Nacional Agraria, Lima.

Mex. Inst. Nac. Invest. Agr. SAG. Circ. CIANO—Mexico Instituto Nacional de Investigaciones Agricolas, Secretaria de Agricultura y Ganaderia, Centro de Investigaciones Agricolas del Noroeste Circular.

Minas Gerais Brasil Dep. Prod. Veg. Bol. Agr.—Minas Gerais, Brasil, Departamento de Produção Vegetal, Boletim de Agricultura.

Min. Agr. (Rio de Janeiro) S.I.A.—Ministério da Agricultura (Rio de Janeiro), Serviço de Informação Agricola.

Miss. Farm Res.—Mississippi Farm Research.

Miss. State Univ. Coop. Ext. Serv. Inform. Sheet—Mississippi

State University Cooperative Extension Service Information Sheet.

Mo. Agr. Exp. Sta. Res. Bull.—Missouri Agricultural Experiment Station Research Bulletin.

Monserrat Bot. Sta. Rep.—Monserrat. Report on the Botanic Station.

N. Amer. Entomol.—North American Entomologist.

N. C. Agr. Exp. Sta. Annu. Rep.—North Carolina Agricultural Experiment Station Annual Report.

N. C. State Univ. Agr. Ext. Serv. Insect Notes, Grains & Soybeans Note—North Carolina State University Agricultural Extension Service Insect Notes, Grains and Soybeans Note.

Okla. Agr. Exp. Sta. Bien. Rep.—Oklahoma Agricultural Experiment Station Biennial Report.

Okla. Agr. Exp. Sta. Mimeo. Circ.—Oklahoma Agricultural Experiment Station Mimeographed Circular.

Okla. Agr. Exp. Sta. Rep.—Oklahoma Agricultural Experiment Station Report.

P.R. Agr. Exp. Sta. Bull.—Puerto Rico Agricultural Experiment Station Bulletin.

P. R. Fed. Exp. Sta. (Mayaguez) Circ.—Puerto Rico Federal Experiment Station (Mayaguez) Circular.

P. R. Fed. Exp. Sta. (Mayaguez) Rep.—Report of the Federal Experiment Station in Puerto Rico (Mayaguez).

Pointe-a-Pitre Guadeloupe Sta. Agr. Rapp.—Pointe-a-Pitre, Guadeloupe, Station Agronomique Rapport.

Proc. Assoc. S. Agr. Workers—Proceedings of the Association of Southern Agricultural Workers.

Proc. Cotton States Br. Amer. Assoc. Econ. Entomol.—Proceedings of the Cotton States Branch, American Association of Economic Entomologists.

Proc. La. Acad. Sci.—Proceedings of the Louisiana Academy of Sciences.

Proc. N. Cent. Br. Entomol. Soc. Amer.—Proceedings of the North Central Branch, Entomological Society of America.

Proc. Soil Crop Sci. Soc. Fla.—Proceedings of the Soil and Crop Science Society of Florida.

Proc. Tall Timbers Conf. Ecol. Anim. Contr. Habitat Manage.—Proceedings of the Tall Timbers Conference on Ecological Animal Control by Habitat Management.

Proc. 10th Int. Congr. Entomol. (Montreal)—Proceedings of the Tenth International Congress of Entomology (Montreal).

Proc. Zool. Soc. London—Proceedings of the Zoological Society of London.

Res. Farming (N. C. Agr. Exp. Sta.)—Research and Farming (North Carolina Agricultural Experiment Station).

Rev. Comerc. Trabajo (Cuba)—Revista de Agricultura, Comercio y Trabajo (Cuba).

Rev. Agr. P. R.—Revista de Agricultura de Puerto Rico.

Rev. Asoc. Ing. Agron.—Revista de la Asociacion de Ingenieros Agronomos.

Rev. Ceres.—Revista Ceres.

Rev. Chilena Entomol.—Revista Chilena de Entomologia.

Rev. Entomol. (Rio de Janeiro)—Revista de Entomologia (Rio de Janeiro).

Rev. Fac. Agron. Univ. Repub. Uruguay—Revista de la Facultad de Agronomia, Universidad de la Republica, Uruguay.

Rev. Fac. Agron. Vet. Univ. Rio Grande do Sul—Revista de Faculdade de Agronomia e Veterinaria da Universidade do Rio Grande do Sul, Brasil.

Rev. Fitotec. Latinoamer.—Revista Fitotecnia Latinoamericana.

Rev. Ind. Agr. Tucuman—Revista Industrial y Agricola de Tucuman.

Rev. Inst. Bolsa Cereales—Revista Institucional de la Bolsa de Cereales.

Rev. Peru. Entomol.—Revista Peruana de Entomologia.

Rice J.—Rice Journal.

Santiago de las Vegas Cuba Estac. Exp. Agron. Circ.—Santiago de las Vegas, Cuba, Estacion Experimental Agronomica Circular.

Santiago de las Vegas Cuba Estac. Exp. Agron. Informe—Santiago de las Vegas, Cuba, Estacion Experimental Agronomica Informe.

Secr. Est. Neg. Agr. Ind. Comerc. S.I.P.A. (Ser. A)—Secretaria de Estado dos Negócios da Agricultura, Indústria e Comércio, Secção de Informações e Propaganda Agricola (Serie A), Porto Alegre, Rio Grande do Sul, Brasil.

Soil Sci. Soc. Amer. Proc.—Soil Science Society of America Proceedings.

Solo Cent. Acad. "Luiz de Queiroz" Univ. São Paulo—Solo, Centro Academico "Luiz de Queiroz" Universidade de São Paulo, Brasil.

Soybean Dig.—Soybean Digest.

Sugar Bull.—The Sugar Bulletin.

Tenn. Agr. Exp. Sta. Bull.—Tennessee Agricultural Experiment Station Bulletin.

Tenn. Agr. Exp. Sta. Ext. Serv. Publ.—Tennessee Agricultural Experiment Station Extension Service Publication.

Trans. Brit. Mycol. Soc.—Transactions of the British Mycological Society.

Trans. Entomol. Soc. London—Transactions of the Entomological Society of London.

Trop. Agr. (Trinidad)—Tropical Agriculture (Trinidad).

Tucuman Estac. Exp. Agr. Publ. Misc.—Tucuman, Argentina, Estacion Experimental Agricola Publicacion Miscelanea.

U.S. Dep. Agr. Agr. Handb.—United States Department of Agriculture, Agriculture Handbook.

U.S. Dep. Agr. Agr. Res. Serv. Rep. State Agr. Exp. Stas.—United States Department of Agriculture, Agricultural Research Service, Report on the State Agricultural Experiment Stations.

U.S. Dep. Agr. Bur. Entomol. Bull.—United States Department of Agriculture, Bureau of Entomology Bulletin.

U.S. Dep. Agr. Bur. Entomol. Plant Quar. E Ser.—United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, E Series.

U.S. Dep. Agr. Farmers Bull.—United States Department of Agriculture Farmers' Bulletin.

U.S. Dep. Agr. Leafl.—United States Department of Agriculture Leaflet.

U.S. Dep. Agr. Off. Exp. Stas. Rep.—United States Department of Agriculture, Report of the Office of Experiment Stations.

U.S. Dep. Agr. Rep. Chf. Bur. Entomol. Plant Quar.—United States Department of Agriculture, Report of the Chief of the Bureau of Entomology and Plant Quarantine.

U.S. Dep. Agr. Tech. Bull.—United States Department of Agriculture Technical Bulletin.

U.S. Dep. Agr. Yearb. Agr.—United States Department of Agriculture, Yearbook of Agriculture.

Univ. Buenos Aires Fac. Agron. Vet. Publ. In.—Universidad de Buenos Aires Facultad de Agronomia y Veterinaria Publicacion Interna.

Univ. Ga. Coop. Ext. Serv. Leafl.—University of Georgia Cooperative Extension Service Leaflet.

Uruguay Min. Agr. Gan. Centro Invest. Sanid. Veg. Publ. Tec. (Ser. Zool. Agr.)—Uruguay Ministerio de Agricultura y Ganaderia, Centro de Investigaciones de Sanidad Vegetal, Publicacione tecnica (Serie Zoologia y Agricultura).

Va. Polytech. Inst. Agr. Ext. Serv. Circ.—Virginia Polytechnic Institute Agricultural Extension Service Circular.

Va. Polytech. Inst. Ext. Div. Contr. Ser.—Virginia Polytechnic Institute Extension Division Control Series.

Verh. K. K. Zool.-Bot. Ges. Wien—Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien.

West Indian Bull.—West Indian Bulletin.

West Indies Imp. Dep. Agr. Pamph. Ser.—Imperial Department of Agriculture for the West Indies, Pamphlet Series.

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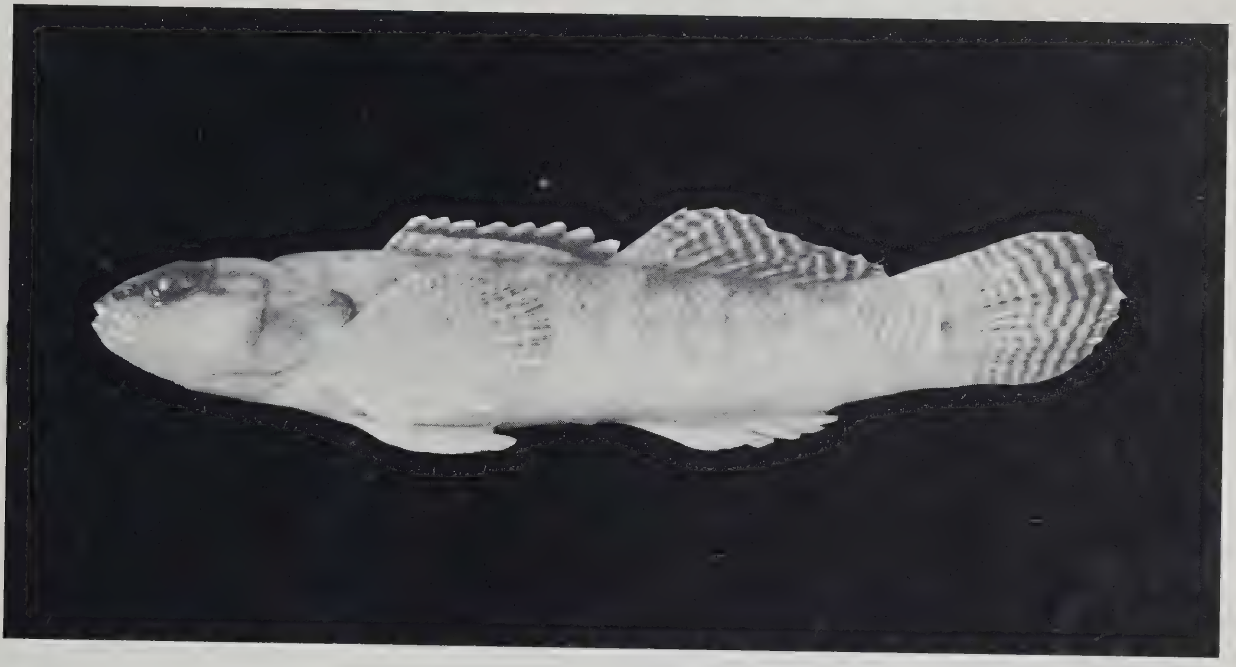
THE LIFE HISTORY OF THE STRIPETAIL DARTER, *ETHEOSTOMA KENNICOTTI*, IN BIG CREEK, ILLINOIS

Lawrence M. Page



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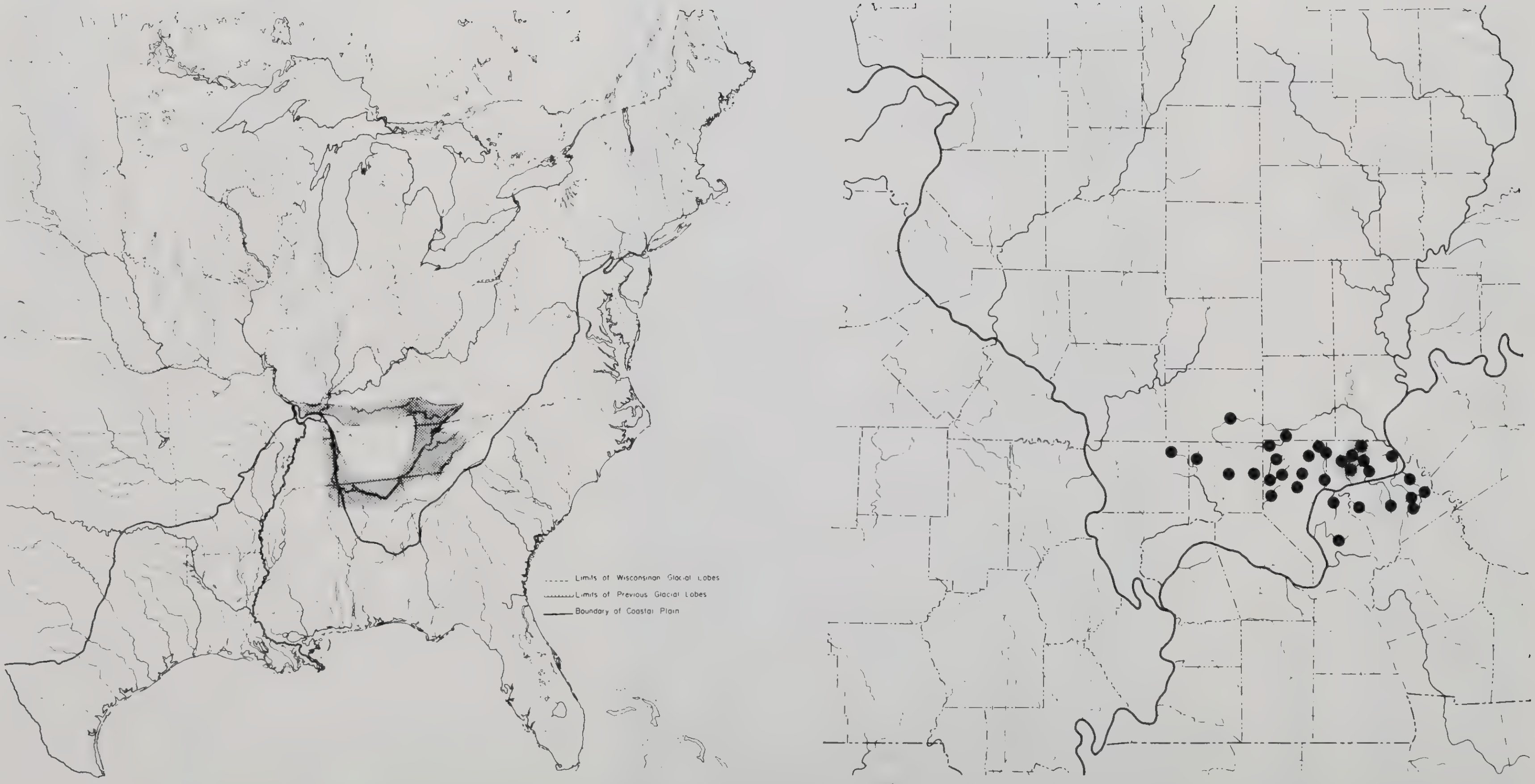
Limits of Wisconsinan Glacial Lobes
Limits of Previous Glacial Lobes
Boundary of Coastal Plain

Fig. 1. — The total range (left) of *Etheostoma kennicotti* and the distribution of the species in Illinois and adjacent Kentucky (right). The study area is shaded.

THE LIFE HISTORY OF THE STRIPETAIL DARTER, *ETHEOSTOMA KENNICOTTI,* IN BIG CREEK, ILLINOIS

Lawrence M. Page

THIS REPORT on the life history of *Etheostoma kennicotti* in Big Creek, Hardin County, Illinois, is the second of three reports on studies completed on species of the subgenus *Catonotus* in southeastern Illinois and the adjacent area of Kentucky between October 1970 and April 1974. The first report was on *E. squamiceps* (Page 1974); the third will be on *E. obeyense.*

E. kennicotti was described by Putnam (1863) from specimens collected by Robert Kennicott in "a rocky brook in Southern Illinois." The range of *E. kennicotti* (Fig. 1) includes the Ohio drainage of southern Illinois, tributaries of the Ohio River in a small area in extreme northwestern Kentucky, the Green River system in Kentucky, the upper Cumberland River system in Kentucky and Tennessee, and Tennessee River tributaries in Tennessee, Alabama, Mississippi, and Georgia. Morphological descriptions of *E. kennicotti* are found in Putnam (1863:3), Jordan & Evermann (1896:1098), Forbes & Richardson (1908: 311–312) — under the name *E. obeyense,* Moore (1968:150), and Collette & Knapp (1966:20–21).

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STUDY AREA, METHODS

The study area, Big Creek in Hardin County, Illinois (Fig. 1), was the same area in which *E. squamiceps* was studied (Page 1974) and is described by Lewis (1957) and Page (1974:3–4). Big Creek is a clear, spring-fed direct tributary of the Ohio River with many gravel riffles, shallow slab rock pools, and deeper sand and gravel-bottom pools (hereafter referred to as non-slab pools).

The methods of study were the same as for *E. squamiceps* (Page 1974:4–5). The study of *E. kennicotti* began on 6 October 1970 and was terminated on 21 April 1974. A total of 1,380 specimens was preserved and examined. Unless stated otherwise, measurements in the text are standard lengths. For certain comparisons darters were divided into young (through 12 months) and adult (over 12 months) age groups.

HABITAT

Similar seining efforts in each of the three major habitats in Big Creek (gravel riffles, slab pools, and non-slab pools) each month during the study revealed a strong preference of adult *E. kennicotti* for slab pools (Table 1). Young *E. kennicotti* also usually preferred slab pools to riffles and non-slab pools but not as rigidly as adults, and at times were more common in the deeper non-slab pools. *E. kennicotti* were also most abundant in slab pools at other localities in Illinois, Kentucky, and Tennessee at which collections were made during the course of this study.

The preferred habitat of *E. kennicotti* is best described as the shallow, slab-rock-bottomed pools characteristic of upper elevation headwater streams (Fig. 2). The slab rocks are used for cover, and *E. kennicotti* were observed darting from beneath one rock to another, seldom remaining exposed for an extended period of time.

Although *E. kennicotti* and the closely related *E. squamiceps* share the strong association with slab stones, the preference of *E. kennicotti* for slab pools is in sharp contrast to the usual preference of *E. squamiceps* for slab riffles (Page 1974:6). In southern Illinois the 10 species most often found with *E. kennicotti* (in descending order of association, *Pimephales notatus, Semotilus atromaculatus, Fundulus olivaceous, Notropis chrysocephalus, Campostoma anomalum, Lepomis megalotis, Notropis umbratilis, Etheostoma caeruleum, E. squamiceps, Erimyzon oblongus)* are those most successfully utilizing stream headwaters.

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TABLE 1. — Habitat distribution by percentages of *Etheostoma kennicotti* collected in Big Creek between 25 August 1971 and 19 June 1973.

Month	Number Collected	Percentages of *E. kennicotti* in Slab Pools	 Gravel Riffles	 Non-slab Pools
		Adults		
January	17	82	0	18
February	14	93	0	7
March	17	100	0	0
April	9	78	11	11
May	87	47	0	53
June	24	88	0	12
July	36	97	3	0
August	50	100	0	0
September	48	81	19	0
October	51	49	14	37
November	14	86	7	7
December	29	93	7	0
		Young		
January	44	45	0	55
February	50	2	0	98
March	45	60	0	40
April	16	75	0	25
July	17	76	0	24
August	67	81	0	19
September	90	78	14	8
October	51	74	10	16
November	71	59	1	40
December	39	87	13	0

REPRODUCTION

Reproductive Cycle of the Male

As the spawning season approached, the genital papilla (Fig. 3) of the male enlarged, and, in contrast to the small and translucent testes of the nonbreeding male, the testes became large, white, and spongy. Breeding tubercles did not develop.

As in other darters, including other species of *Catonotus*, the color and intensity of the pattern of the male changed as the spawning season approached. The change was mainly an increase in melanization of the head similar to that described for *E. flabellare* (Lake 1936-818; Winn 1958*b*:172; Cross 1967:319) and the development of an orange-gold body color sharply contrasting with the white to light brown body of females and nonbreeding males.

The most extreme breeding pigmentation patterns were observed on spawning and nest-guarding males (Fig. 4 and 7). In contrast to females and nonbreeding males which have nearly identical pigment patterns, the body (especially the venter) was orange-gold in color, and the head, nape, and breast were darkened (although not nearly to the extreme of *E. squamiceps* breeding males). The orange knobs on the spines of the dorsal fin were swollen. The knobs and a thin, black submarginal band sharply contrasted with the unpigmented proximal portion of the dorsal fin membrane. The pelvic fins, and in some males the anal fin, were milky white. The rays of the pectoral fins were outlined by rows of melanophores and were highly visible against the gold sides of the male. The gold iris of the eye appeared enlarged and especially prominent. The black vertical banding on the caudal and soft dorsal fins was much stronger and more visible than in nonbreeding individuals. The mottling on the sides of the body was partially obscured by variously devel-

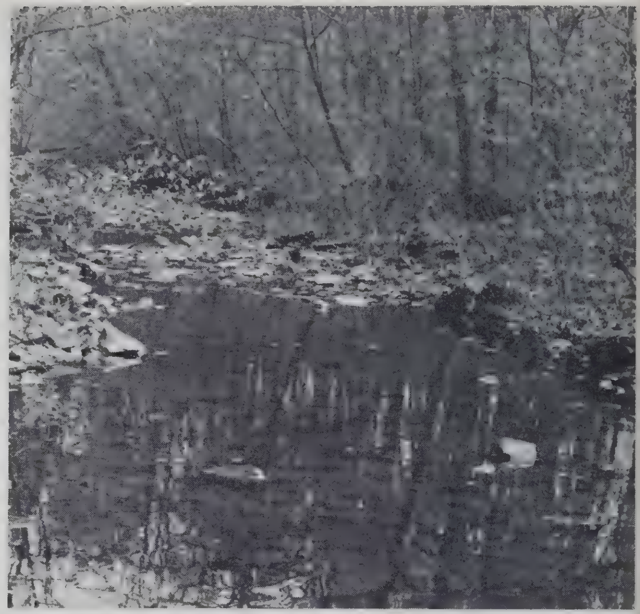

Fig. 2. — Slab pool in the headwaters of Big Creek, Hardin County, Illinois.

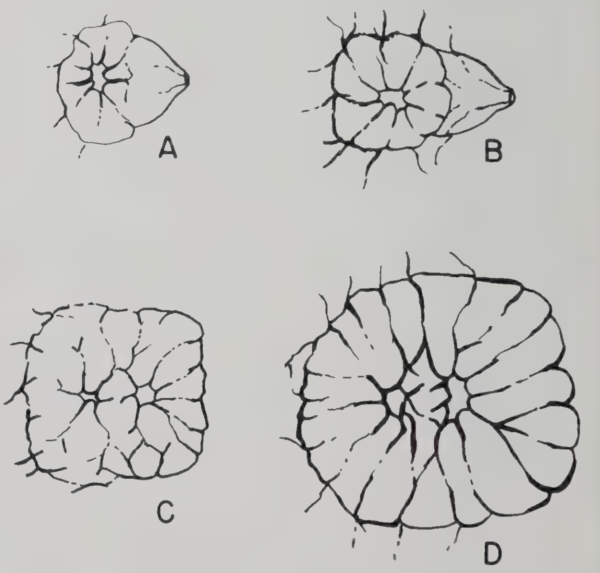

Fig. 3. — Genital papillae of *Etheostoma kennicotti*. A, nonbreeding male; B, breeding male; C, nonbreeding female; and D, breeding female. The nonbreeding specimens were 2+ years old, collected on 20 July 1971; the breeding specimens were also 2+ years old, collected on 16 May 1971.

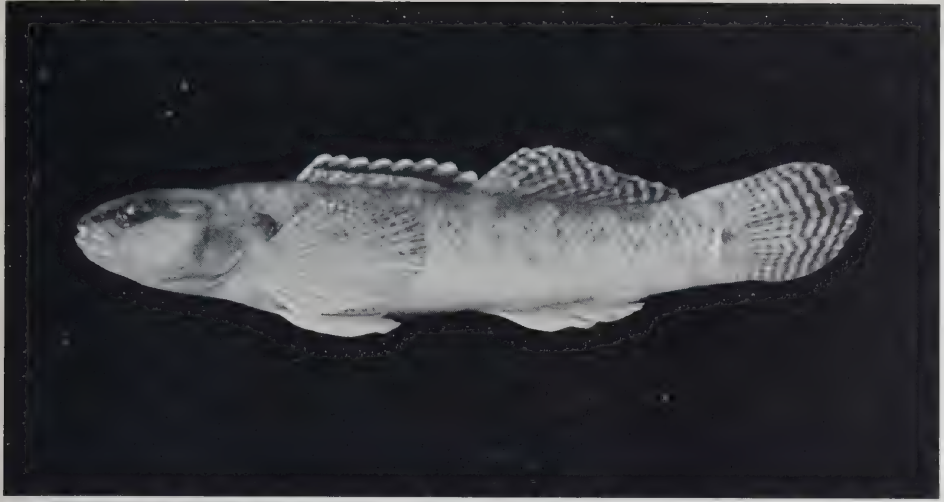

Fig. 4. — Breeding male *Etheostoma kennicotti* 50.4 mm in standard length collected in Big Creek on 20 March 1974. Pigments have been somewhat subdued by preservation.

oped vertical banding, strong on some males and weak on others. The black humeral spot was prominent.

In larger breeding males the flesh of the head, and to a lesser extent that of the nape, becomes swollen. The swollen flesh may have a secretory function similar to that hypothesized for swollen flesh on *E. flabellare* by Cross (1967:320) or sensory and secretory functions similar to those discussed for the swelling of the head and nape of *Pimephales promelas* breeding males (Smith & Murphy 1974).

In March and April, males of *E. kennicotti* selected cavities under slab rocks as future nesting sites and defended them as breeding territories. The cavities were cleaned of silt and debris, mainly by vigorous tail-wagging motions as described for *E. squamiceps* (Page 1974:7).

Nesting territories of *E. kennicotti* in Big Creek were mostly established in the shallow (usually less than 30 cm), upstream slab pools also occupied heavily by *E. squamiceps*. In the spring the current in these pools was slight but sufficient to sweep most debris downstream. Less commonly, nesting territories were established among the concentrations of slab rocks at the margins of deeper pools. Deep water (over 40 cm) was usually avoided, and very rarely were *E. kennicotti* nests found in swift water.

In contrast to *E. squamiceps*, in which only the large males were found spawning, 1-year-old *E. kennicotti* as small as 35 mm were sexually mature and successful spawners. However, most nest territories found were held by large males, and large males presumably do most of the spawning.

Reproductive Cycle of the Female

As in other species of darters, generally the largest females of *E. kennicotti* developed mature ova earliest in the season. Females that were about 30 mm by 1 year of age developed mature ova and were capable of spawning. A few females as small as 27 mm developed mature ova in late May but probably did not successfully spawn so late in the season.

Females did not undergo changes in coloration associated with the breeding season. The only marked morphological changes were the gross distention of the belly caused by maturing ova and the enlargement of the genital papilla (Fig. 3). Enlargement of the papilla began in most females by February or March; distention of the belly was apparent from only a few days to 2–3 weeks before spawning.

Small white ova began appearing in the females between September and December, appearing earliest in the largest individuals. A minimum size of approximately 20 mm was reached before white ova were discernible. Larger yellow ova were found as early as January in females 30 mm and larger, and appeared later in slower growing individuals. Large, maturing orange ova were present from March to May. Prior to spawning time, the mature ova became translucent.

The largest (and oldest) females produced the largest number of mature ova. In 17 ripe females collected in March, April, and May, the number of mature ova varied from 24 to 130 (Table 2). For these females the relationship between the number of mature ova (F) and adjusted body weight (W) was $F = 2.00 + 61.58W$, with $r = 0.631$, and between the number of mature ova and the standard length (L) was $\log F = -3.061 + 3.020 \log L$, with $r = 0.668$.

Estimates of the number of eggs laid in aquaria by five females (from 40 to 48 mm) were 20, 30, 40, 45, and 80. Eggs averaged 2.1 mm in diameter, were translucent, and contained a single oil droplet.

Ovaries of postspawning females collected in June and July were small compared to those of prespawning females collected from March through May (Fig. 5). Ovaries increased markedly in size between the

TABLE 2. — Relationship between size, age, and ovary weight of *Etheostoma kennicotti* females and the number of mature ova produced. An age of 1 year = 11–13 months, 2 years = 23–25 months.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Age in Years	Ovary Weight in Grams	Number of Mature (Orange or Translucent) Ova
30	0.35	1	0.06	24
33	0.59	1	0.09	35
34	0.59	1	0.15	38
34	0.63	1	0.11	44
34	0.66	1	0.18	58
35	0.57	1	0.09	36
35	0.62	1	0.11	40
36	0.72	1	0.12	38
38	0.80	1	0.08	28
39	0.89	1	0.15	49
39	0.82	2	0.08	65
40	1.06	2	0.20	56
41	1.08	2	0.11	53
41	1.06	2	0.12	70
44	1.40	2	0.15	126
45	1.31	2	0.12	58
48	1.73	2	0.17	130

[a] Adjusted body weight is the specimen's weight after removal of the ovaries, stomach, intestine, and liver.

postspawning period and the spawning period the following spring. For the females examined, the relationship between the weight of the ovaries/the adjusted body weight (Y) and the month (X), with June = 1 and May = 12, was log Y = 0.500 + 0.130X, with r = 0.931 (Fig. 5).

The proportionally largest ovaries (equalling 27.3 percent of the adjusted body weight) found were in a 1-year-old, 34-mm female collected on 16 April 1973. In the 17 females represented in Table 2, ovary-weight to adjusted-body-weight ratios ranged from 0.092 to 0.273 and averaged 0.152.

Spawning

E. kennicotti spawned on the undersides of the slab rocks (Fig. 6) previously selected and guarded as nesting territories by the males. In Big Creek, territories held by breeding males were found as early as 20 March, and nests with eggs were found from 5 April to 27 May. Most spawning occurred in late April or early May when water temperatures were from 14 to 20°C. Field observations and examinations of preserved specimens collected during all months of the year indicated April and May to be the spawning period throughout the range of the species (Table 3).

Nine spawnings of *E. kennicotti* captured in Big Creek occurred in laboratory aquaria; four were observed. Four of the nine spawnings occurred in the morning, four in the afternoon, and one during the night or early morning. Water temperatures varied from 19 to 22°C.

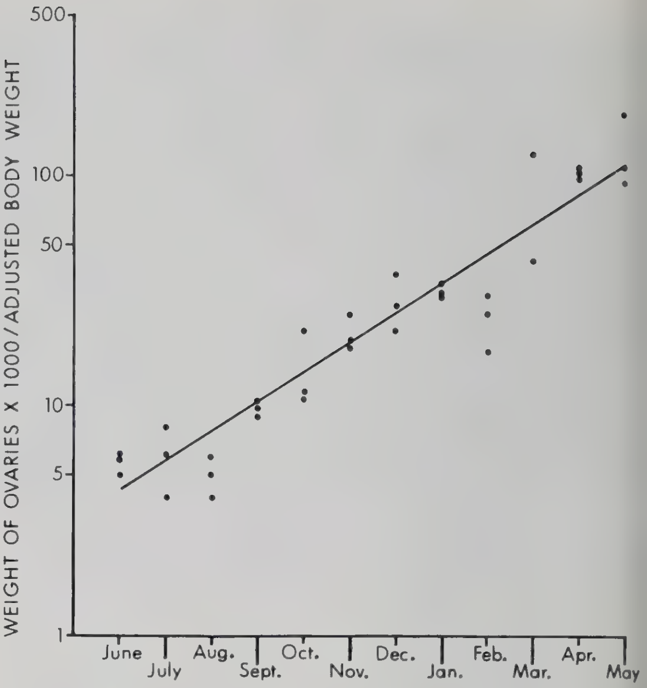

Fig. 5. — Monthly variations in ovarian weight relative to adjusted body weight of *Etheostoma kennicotti*. The vertical axis is on a logarithmic scale. Ovaries from specimens collected June to March were from 1+-year-old females (14–23 months), in April from 2-year-olds (24 months), and in May from 2+-year-olds (25 months).

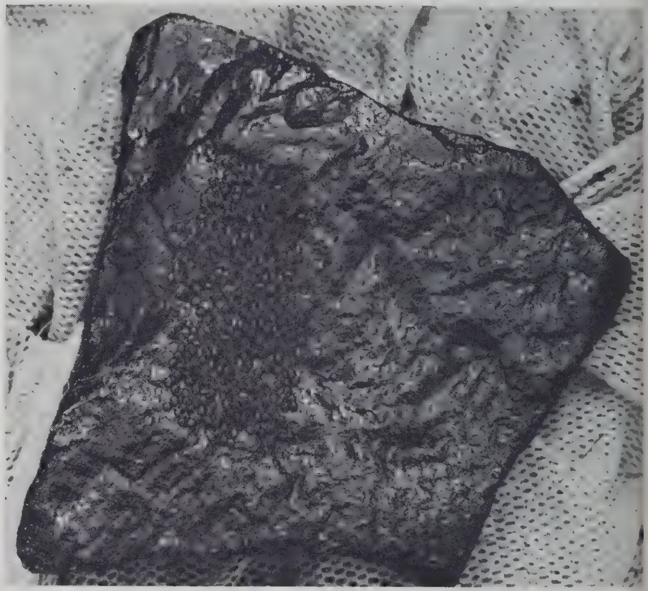

Fig. 6. — Eggs of *Etheostoma kennicotti* on the underside of a stone removed from a slab pool in the headwaters of Big Creek on 22 April 1971.

Males left the nest stone to court females only briefly and only when a female was near the stone. In contrast, when a female swam under the stone she was vigorously courted by the male. Courting consisted mainly of the male laterally displaying his

TABLE 3.—Collections of breeding *Etheostoma kennicotti.*

Locality	Collection Date	Remarks
g Creek, Hardin Co., Ill. (INHS[a])	17 April–3 May 1971	Spawning when collected.
g Creek, Hardin Co., Ill. (INHS)	16 April–30 May 1973	Spawning when collected.
g Creek, Hardin Co., Ill. (INHS)	5 April–21 April 1974	Spawning when collected.
nting Branch, Pope Co., Ill. (INHS)	19 May 1973	Spawning when collected.
k Creek, Union Co., Ill. (INHS)	19 May 1973	Females in extreme breeding condition.
aden Branch, Anderson Co., Tenn. (UMMZ[b]103697)	10 April 1937	Females in extreme breeding condition.
eek, Anderson Co., Tenn. (UMMZ 103742)	26 April 1937	Females in extreme breeding condition.
ib., Big South Fork, Scott Co., Tenn. (UT[c]91.212)	26 May 1968	Females in extreme breeding condition.
sick Creek, Sevier Co., Tenn. (NLU[d]19192)	22 April 1971	Females in extreme breeding condition.

[a] Illinois Natural History Survey.
[b] University of Michigan Museum of Zoology.
[c] University of Tennessee.
[d] Northeast Louisiana University.

eeding coloration and spread fins and wagging his l near or against the female. Occasionally the male dged the female with his snout.

When ready to spawn the female inverted under-ath the nest stone by rolling to one side (Fig. 7). males were observed to remain inverted for as ng as an hour, during which time they rested by vering their weight onto the substrate beneath the one. When not resting, the female rose to the lower rface of the stone and darted over it in short, ky movements, apparently selecting a site for egg position.

When laying eggs, the female pressed her genital pilla against the stone and was joined by the male ho, after inverting by rolling to one side, positioned nself alongside and against the female, usually in head-to-tail position and less often in a head-to-head sition (Fig. 7). Both trembled as eggs and sperm ere released. Then the male returned to an up-ght position and the female remained inverted. me females were observed to lay eggs even though e male remained upright for an extended period.

During the trembling action of egg laying, which sted 3–5 seconds, the female moved forward slightly, positing one or two eggs. The periods between g-laying sessions varied greatly and were perhaps olonged due to the wariness of the fish while ing observed. The eggs were laid in a concentrated ea but never on top of one another.

As many as four females contributed to the aquar-im nest of a male, but only one female at a time as allowed under the nest. Eggs by a second female ere added to the egg mass began by the first male to spawn, and, as in *E. squamiceps,* the esence of eggs is probably a strong stimulus for males to spawn (Page 1974:14). In aquaria all fe-ales after the first to spawn added eggs only to the isting nest; no new nests were begun even though her males had established territories under stones id actively courted the females. One *E. kennicotti* male spawned a second time after the eggs in his first nest had all hatched several days earlier.

Heavy feeding stimulated spawning in aquaria. Darters did not spawn when lightly fed but spawned readily after a heavy feeding of chironomid larvae.

Counts and estimates of the numbers of eggs in 12 nests of *E. kennicotti* found in Big Creek were 50, 80, 80, 85, 130, 200, 220, 300, 325, 325, 350, and 400 (mean = 212). Several of these nests contained more eggs than the largest number of mature ova (130) found in a preserved female and must have contained eggs from more than one female. Eggs in nests averaged 2.1 mm in diameter.

Males vigorously guarded the nest against invaders, including fishes and crayfishes slightly larger than themselves. When lifting a nest stone caused the male to leave the nest, he soon returned and again guarded the nest. Females did not guard the nests.

The breeding coloration of the male was retained during the very active period of nest guarding. The eggs were constantly examined visually by the male, who periodically nipped at the eggs, presumably to remove invading organisms or dead or diseased eggs. The continuous darting back and forth beneath the nest resulted in the eggs being constantly brushed by the dorsal fins.

The same slab pools used in Big Creek by *E. kennicotti* were used as spawning grounds by *E. squamiceps,* although spawning activity in *E. kennicotti* peaked slightly later (late April and early May for *E. kennicotti;* early April for *E. squamiceps*). *E. squamiceps* also utilized spring runs in Big Creek as spawning grounds whereas *E. kennicotti* did not. *E. kennicotti* utilized the rocky margins of deeper pools but *E. squamiceps* did not.

The spawning behavior of *E. flabellare* was described by Lake (1936) and by Winn (1958*a*, 1958*b*) and that of *E. squamiceps* by Page (1974). The behavior of *E. kennicotti* is more similar to that of *E. flabellare.* In both *E. kennicotti* and *E. flabel-*

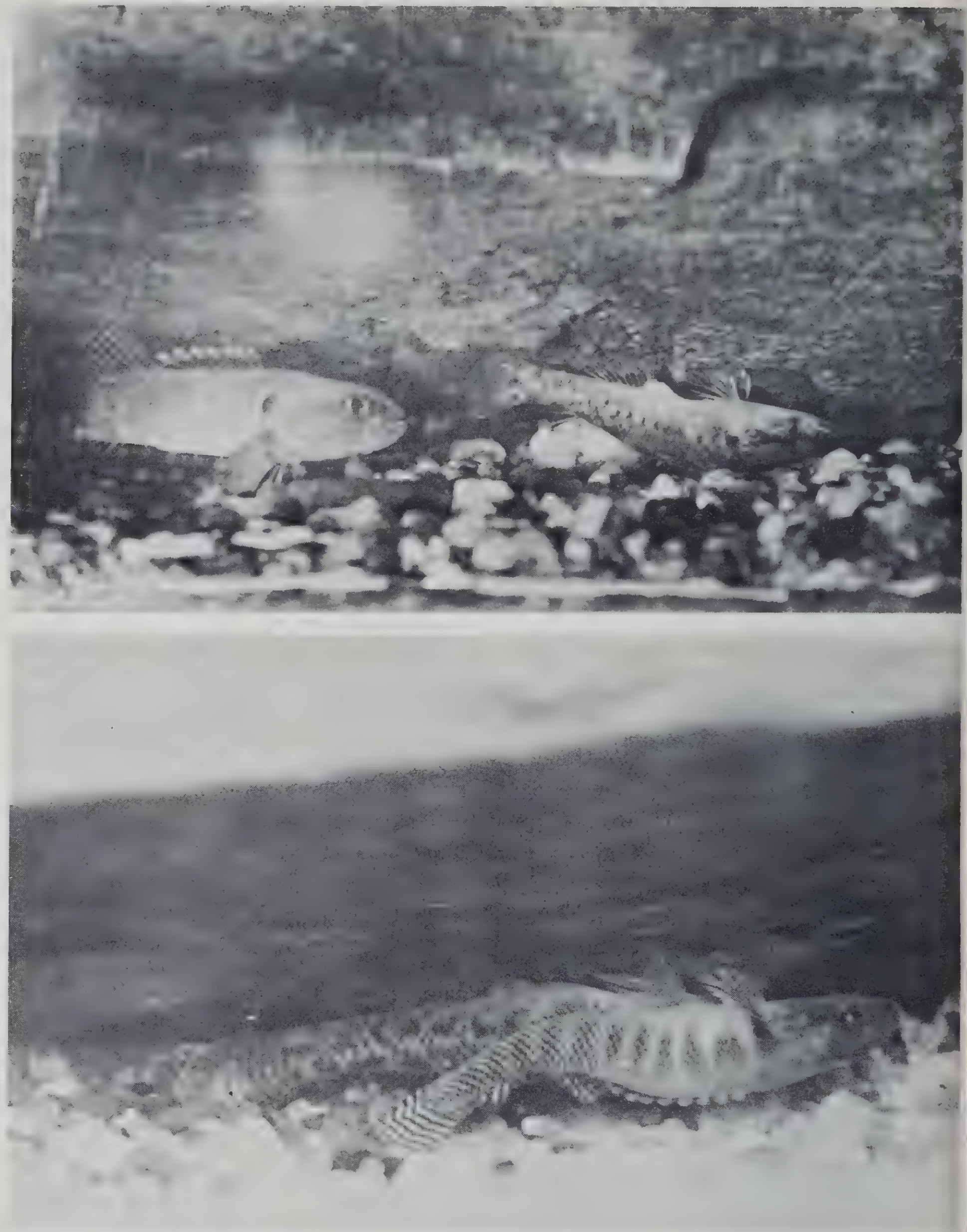

Fig. 7. — *Etheostoma kennicotti* spawning in aquaria. In the top photo a female has inverted beneath a stone guarded by a male. In the bottom photo the male is inverting to position himself alongside the female.

lare, but not in *E. squamiceps,* the male and female normally align head-to-tail during egg laying, the females remain inverted between egg-laying sessions, and the male is usually intolerant of a right-side-up female under the nest stone.

Sexual Dimorphism

Twenty meristic and morphometric characters were tested for sexual dimorphism in 41 specimens over 45 mm from southern Illinois and adjacent Kentucky. In this sample, four characters showed significant ($P < .005$) sexual dimorphism. Females have a significantly higher number of pored lateral-line scales, and males have significantly deeper caudal peduncles, longer caudal fins, and longer soft dorsal fins. Sexual dimorphism in *E. kennicotti* in territorial behavior, coloration, and size are discussed elsewhere in this paper.

DEVELOPMENT AND GROWTH

Eggs incubated in an aquarium at 19–23°C hatched in 145–150 hours (6.0–6.3 days). This incubation period is much shorter than that of *E. squamiceps* (11 days — Page 1974:11) and *E. flabellare* (20–30 days — Lake 1936:826) at a comparable temperature range. Eggs from only one nest were kept alive to hatching.

Hatchlings of *E. kennicotti* (Fig. 8) were 5.7 mm in total length and mostly translucent with only a few melanophores. They had the same well-developed lower jaw and pectoral fins characteristic of *E. squamiceps* (Page 1974:11) and *E. flabellare* hatchlings

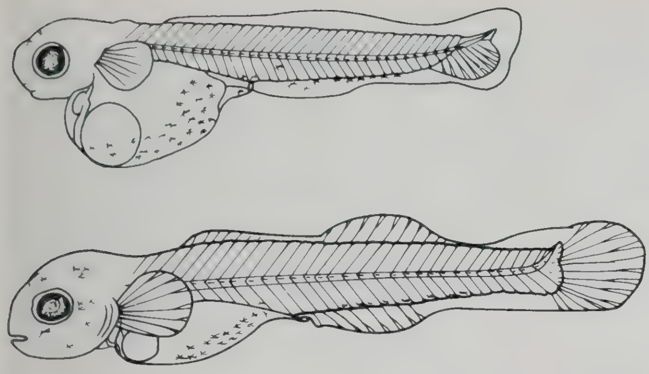

Fig. 8. — *Etheostoma kennicotti* hatchling (5.7 mm total length) and 3-day-old larva (7.2 mm total length).

(Lake 1936:826–827). The spines and rays of the median fins were evident by the third day (Fig. 8).

A series of 39 young *E. kennicotti* ranging from 10 to 20 mm was collected in the study area on 20 July 1971. The color pattern of individuals up to 15 mm consisted of relatively large, dark spots on the sides and dorsum. On specimens over 15 mm the pattern approached that of an adult (Cover Illustration) but the lateral spots remained and the mottling on the dorsum was more subdued than in adults.

Squamation was nearly complete at 10 mm, the scales normally found on the adult being absent only on the belly and anterior dorsum to below the first dorsal fin. At 15 mm, squamation was complete. The lateral-line canal began forming at about 15 mm and at 18 mm extended to beneath the first dorsal fin.

Big Creek *E. kennicotti* grew at a decreasing rate (Fig. 9). The relationship between standard length (Y) and age in months (X) is expressed for males by the equation $Y = -3.11 + 33.02 \log X$, with $r = 0.939$, and for females by the equation $Y = -3.37 + 31.55 \log X$, with $r = 0.911$.

Males grew more rapidly than females (Fig. 9) and by the third year were significantly larger than females ($t = 3.46$, $df = 44$). The largest specimen examined from Big Creek was a 54-mm male collected on 25 March 1972. In the upper Cumberland River system *E. kennicotti* gets considerably larger, and specimens as long as 69 mm have been collected. Table 4 presents the standard lengths of 1- and 2-year-old *E. kennicotti* collected in April 1971 and 1973.

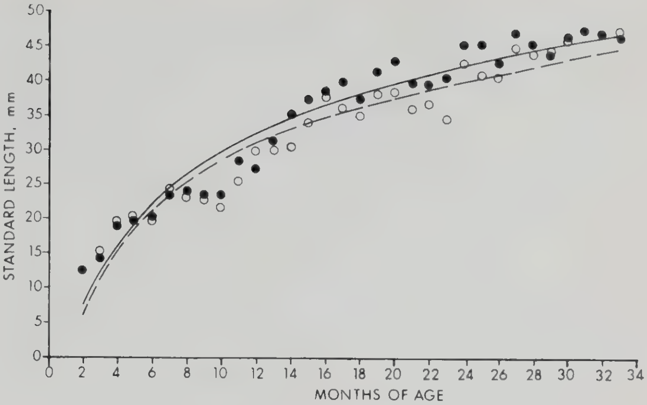

Fig. 9. — Size distribution by age of *Etheostoma kennicotti* collected in Big Creek between 6 October 1970 and 19 June 1973. Black dots represent sample means for males; circles represent sample means for females. In total, 1,380 specimens are represented.

E. kennicotti reached one-half of the first year's mean growth in approximately 16 weeks; this is a longer period than required for *E. squamiceps* (12 weeks — Page 1974:12) and much longer than that required for *E. gracile* (1 week — Braasch & Smith 1967:9) and *Percina phoxocephala* (2 weeks — Page & Smith 1971:9).

DEMOGRAPHY

Density

On four separate dates at approximately 3-month intervals, quantitative samples of *E. kennicotti* were taken in Big Creek by repeatedly seining measured areas of stream until no more individuals were col-

Table 4.—Standard lengths of *Etheostoma kennicotti* collected in Big Creek at 1 and 2 years (12 and 24 months) of age. Specimens were collected in April 1971 and 1973.

Sex and Collection Year	Age	Number	Standard Length		
			Mean	Range	Standard Deviation
Males 1971	1	25	25.9	18.9–35.9	4.7
Males 1973	1	5	34.8	31.0–38.1	2.8
Females 1971	1	54	29.7	19.4–43.5	6.1
Females 1973	1	11	32.9	28.2–39.8	3.7
Males 1971	2	13	45.0	39.8–49.7	3.1
Males 1973	2	3	48.7	47.2–51.4	2.3
Females 1971	2	8	41.8	40.3–43.4	1.4
Females 1973	2	6	43.5	38.3–47.5	3.5

lected. The number collected was transposed into the number per square meter (Table 5).

The highest densities of both young and adults were consistently found in the slab pools, previously noted to be the preferred habitat of *E. kennicotti* (Table 1). With young and adults combined, the greatest density found for *E. kennicotti* in Big Creek was in the slab pools in July (6.5 per m^2).

TABLE 5. — Number of *Etheostoma kennicotti* per square meter collected in Big Creek at approximate 3-month intervals, by habitat. Young were up to 1 year of age, adults over 1 year.

Date	Number Collected	Number of *E. kennicotti* per Square Meter in: Slab Pools	Gravel Riffles	Non-slab Pools
		Adults		
8 July 1972	36	4.71	0.09	0
19 October 1972	35	1.71	0.63	0.97
17 January 1973	11	1.21	0	0
16 April 1973	9	0.95	0.22	0.12
Mean		2.15	0.24	0.27
SD		1.74	0.28	0.47
		Young		
8 July 1972	17	1.75	0	0.23
19 October 1972	17	1.23	0.63	0.26
17 January 1973	10	1.10	0	0
16 April 1973	16	1.61	0	0.47
Mean		1.42	0.16	0.24
SD		0.31	0.32	0.19

Composition

Of the 1,380 *E. kennicotti* collected in Big Creek, 55.7 percent were up to 1 year of age, 41.0 percent were over 1 and up to 2 years of age, and 3.3 percent were over 2 years (Table 6).

Females predominated in the young-of-the-year (−1) age class [1.4 females to 1 male ($\chi^2 = 18.13$; $P < 0.005$)], in the 1+ year class [1.7 to 1 ($\chi^2 = 36.64$; $P < 0.005$)], and in the total sample [1.5 to 1 ($\chi^2 = 47.49$; $P < 0.005$)]. Although predominating significantly in the younger age classes, females were slightly less common than males in the 2+ year class, reflecting the same greater longevity of males found in other darters (e.g. *E. squamiceps* — Page 1974:13).

TABLE 6. — Distribution of sexes and year classes in samples of *Etheostoma kennicotti* collected between 6 October 1970 and 19 June 1973.

Sex	Number by Year Class: −1	1+	2+	Total
Males	325	211	26	562
Females	443	355	20	818
Total	768	566	46	1,380

For *E. squamiceps* a relationship was suggested (Page 1974:13) between the predominance of females and the reduced need for a 1:1 sex ratio during spawning (because only the large males of *E. squamiceps* spawn and because several females may contribute to the nest of one male). Although small as well as large *E. kennicotti* males spawn, probably most successful spawnings are accomplished by the larger males because of the importance of holding a breeding territory, and a reduced necessity for a 1:1 sex ratio during spawning may also be characteristic of *E. kennicotti*.

Survival

Relative survival values (Table 7) for each year of life were calculated for males, females, and total samples of *E. kennicotti*, using the data in Table 6. It was assumed that each age class was collected in proportion to its relative number in the population, that the population was neither increasing nor decreasing, and that the number of fry entering the population each year was constant.

Because approximately one-third of the sampling effort each month was expended in the slab pools, which constitute less than one-third of Big Creek but in which adults tended to be concentrated (Tables 1 and 5), the number of adults in Table 6 probably exaggerates their actual proportion in the population. Survival was therefore computed on the 1+ year class as well as the −1 year class (Table 7).

The shapes of the survival curves for males, females, and total samples (Fig. 10) were similar. All showed a very low survival rate for *E. kennicotti* during the third year of life. No individuals 3 years or older were found and the maximum life-span of *E. kennicotti* in Big Creek is apparently 2+ years. In contrast, the related *E. squamiceps* had a maximum life-span of 3+ years in Big Creek (Page 1974:13–14). The oldest *E. kennicotti* from Big Creek examined were four males 2 years and 9 months old (assuming April hatchings) collected in January of 1971 and 1973.

TABLE 7. — Relative survival of year classes of *Etheostoma kennicotti* expressed as proportions of the −1 year class ($1x^1$) and the 1+ year class ($1x^2$).

Sample	Year Class	Number of Specimens	Survival: $1x^1$	$1x^2$
Males	−1	325	1.000	..
	1+	211	0.649	1.000
	2+	26	0.080	0.123
Females	−1	443	1.000	..
	1+	355	0.801	1.000
	2+	20	0.045	0.056
Total sample	−1	768	1.000	..
	1+	566	0.737	1.000
	2+	46	0.060	0.081

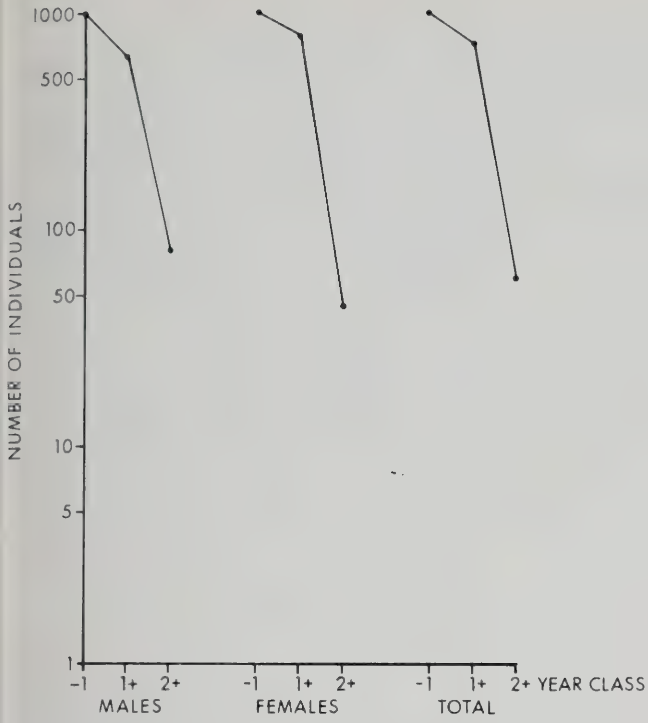

Fig. 10. — Survival curves for *Etheostoma kennicotti* based on the data in the lx¹ column in Table 7 multiplied by 1000. The vertical axis is a logarithmic scale.

Migration

Most spawning occurred in upstream headwater pools; this probably necessitated movement upstream by some individuals prior to the spring spawning period, and possibly a subsequent downstream dispersal during summer or fall. However, both young and adults were most common in slab pools during all seasons (Table 1) and no obvious migrating patterns were noted for *E. kennicotti.*

Territoriality

Observations made on aquarium-held *E. kennicotti* and in the study area indicated that males are strongly territorial, especially during the spawning season, and that females are occasionally territorial. When defending a territory, the male has a darkened head and prominent vertical bars, and the first dorsal fin is held erect, displaying the brilliantly colored gold knobs.

Territories were most vigorously defended during the spawning season and centered about the nest stone. Combats were common and consisted of threat displays (a lateral display in a slight angle with the head lower than the caudal fin, the median fins erect, and the lateral vertical bars prominent), nipping, and tail slapping. Often two combating males circled rapidly, each nipping the tail of the other. The selective advantage for territoriality during the spawning season is evident; as in *E. squamiceps,* the first male to spawn in an aquarium was the only male to spawn.

As in *E. squamiceps* (Page 1974:14) aquarium-held *E. kennicotti* females in the area away from the nest stones became belligerent toward other females and defended nonstationary territories. The coloration of a territorial female is similar to that on a territorial male, with vertical bars and a darkened head, but less well developed.

DIET

Stomach contents of 333 *E. kennicotti* were examined. The contents consisted mostly of immature insects and small crustaceans (Tables 8 and 9), with the predominant food items being chironomid larvae, copepods, mayfly naiads, cladocerans, and ostracods. The variety of food items was less (16 versus 22 taxa) than that found for *E. squamiceps* in the same study area (Page 1974:14–18) even though more specimens of *E. kennicotti* (333 versus 173) were examined. *E. squamiceps* attains a larger size (72 mm standard length) than *E. kennicotti* (54 mm) in Big Creek and therefore can presumably ingest a greater variety of food items.

Small *E. kennicotti* (<21 mm) fed mainly on mayflies, copepods, chironomids, and ostracods; the large ones (>40 mm) fed mainly on mayflies, chironomids, isopods, and amphipods (Table 8).

Some seasonal variation in diet (Table 9) was evident among the 142 specimens of *E. kennicotti* ranging from 31–40 mm (the size class having the largest number of individuals). Chironomids were the major food component during winter and spring; mayflies were the major component from July to November. Stoneflies were heavily consumed in December and January but were absent in the diet from March to November. Food consumption was heaviest in December, January, and March.

E. kennicotti fed in the same way as described for *E. squamiceps* (Page 1974:17), and aquarium-held darters, including nest-guarding males, fed readily on frozen earthworms and live aquatic insects and crustaceans.

INTERACTIONS WITH OTHER ORGANISMS

Competition

In contrast to *E. squamiceps,* which occurs syntopically with all other described species of *Catonotus, E. kennicotti* appears to be limited in distribution, abundance, and size at least in part by the distributions of other species of the subgenus *Catonotus.* This will be examined in more detail by Page and P. W. Smith in a paper on geographic variation in *E. kennicotti.*

The use by *Catonotus* species of slab-rock pools as spawning grounds, and their dependence on slab rocks during all stages of their life histories (Lake 1936, Winn 1958*a*, 1958*b*, Page 1974) seem to result in

TABLE 8.—Stomach contents of *Etheostoma kennicotti* from Big Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred					Mean Number of Food Organisms per Stomach				
	<21 mm (22)	21–30 mm (90)	31–40 mm (142)	41–50 mm (77)	>50 mm (2)	<21 mm (22)	21–30 mm (90)	31–40 mm (142)	41–50 mm (77)	>50 mm (2)
Oligochaeta	..	..	..	1.3	..	..	..	..	0.01	..
Gastropoda	..	..	0.7	1.3	..	..	..	0.01	0.01	..
Crustacea										
Cladocera	9.1	10.0	2.1	1.3	..	0.23	1.79	0.11	0.01	..
Ostracoda	13.6	8.9	3.5	5.2	..	1.14	0.19	0.08	0.12	..
Copepoda	68.2	33.3	9.9	9.1	..	2.27	2.11	0.19	0.13	..
Isopoda Asellidae	..	8.9	6.3	18.2	..	..	0.10	0.06	0.26	..
Amphipoda	4.5	5.6	12.0	14.3	..	0.05	0.07	0.13	0.19	..
Insecta										
Plecoptera	..	14.4	9.2	5.2	..	..	0.32	0.39	0.16	..
Ephemeroptera	86.4	44.4	46.5	53.2	..	1.45	0.72	0.64	0.78	..
Odonata Anisoptera	..	1.1	0.7	..	..	..	0.01	0.01	..	..
Megaloptera	..	..	..	..	50.0	..	..	..	..	0.50
Trichoptera	4.5	..	7.0	5.2	50.0	0.05	..	0.08	0.08	0.50
Coleoptera										
Psephinidae	..	..	0.7	..	..	..	..	0.01	..	..
Others	4.5	6.7	1.4	5.2	..	0.09	0.07	0.01	0.06	..
Diptera										
Chironomidae	50.0	62.2	51.4	42.9	100.0	1.00	2.91	2.85	2.70	3.00
Others	..	..	3.5	5.2	..	..	..	0.04	0.05	..

competition among the species. Although differences in nonspawning habitat preference may be recognized, all species studied utilize slab pools as spawning grounds and, when syntopic, probably compete for space. The staggering of spawing periods (Page 1974:18) may help reduce competition among certain species.

Predation

No information on predation on *E. kennicotti* has been published, and there was no evidence of predation in this study. As potential predators five *Esox americanus* and 12 *Lepomis cyanellus* collected with *E. kennicotti* in Big Creek were preserved and later examined. No ingested *E. kennicotti* were found.

Parasitism

Nine piscicolid leeches were found on the caudal and pectoral fins of eight of the *E. kennicotti* collected from Big Creek during October (1970 and 1971) and November (1970). No other ectoparasites were noted on the 1,380 specimens examined.

In the 333 specimens from which stomach contents were examined, 33 contained a total of 63 spiny-headed worms (presumably *Acanthocephalus jacksoni*) in their intestines. This is a much lower infestation than was found in *E. squamiceps* in the same study area (Page 1974:19). As in *E. squamiceps*, more worms were found in the larger *E. kennicotti* (up to 5 worms). In *E. kennicotti*, infestation occurred only from November through March. The absence of worms in specimens collected from June through October is similar to the infestation pattern found in *E. squamiceps*.

Hybridization

The only known hybrid of *E. kennicotti* is a 40-mm *E. squamiceps* x *E. kennicotti* male, described by Page (1974:19–20) and shown in Fig. 11.

Species recognition during spawning apparently depends mainly on visual cues perceived by the female, as the color and courting behavior of the breeding male suggest. In aquaria, male *E. kennicotti* were observed courting females of *E. squamiceps* and *E. obeyense*, and on two separate dates spawning occurred between a male *E. kennicotti* and a female *E. obeyense*. The eggs hatched but the young lived only a few days.

SUMMARY

The life-history information on *E. kennicotti* collected in Big Creek between 6 October 1970 and 21 April 1974 is summarized in Table 10.

Table 9.—Stomach contents of *Etheostoma kennicotti* ranging in size from 31 to 40 mm from Big Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred												Mean Number of Food Organisms Per Stomach											
	Jan. (10)	Feb. (17)	Mar. (15)	Apr. (13)	May (22)	June (1)	July (10)	Aug. (19)	Sept. (7)	Oct. (10)	Nov. (8)	Dec. (10)	Jan. (10)	Feb. (17)	Mar. (15)	Apr. (13)	May (22)	June (1)	July (10)	Aug. (19)	Sept. (7)	Oct. (10)	Nov. (8)	Dec. (10)
Gastropoda	..	..	..	..	..	..	..	..	14.3	..	..	..	..	..	..	..	..	..	..	..	0.14	..	..	..
Crustacea																								
Cladocera	..	..	13.3	..	..	..	..	..	..	..	12.5	..	..	..	1.00	..	..	..	..	..	..	..	0.13	..
Ostracoda	..	..	..	..	13.6	..	10.0	..	14.3	..	..	..	..	..	..	..	0.23	..	0.40	..	0.43	..	..	..
Copepoda	40.0	11.8	..	30.8	13.6	..	..	..	..	..	..	10.0	0.90	0.18	..	0.77	0.18	..	..	..	..	..	..	0.10
Isopoda																								
Asellidae	..	11.8	6.7	..	4.5	..	..	10.5	..	20.0	12.5	20.0	..	0.12	0.07	..	0.05	..	..	0.11	..	0.20	0.13	0.20
Amphipoda	10.0	5.9	6.7	30.8	18.2	..	10.0	10.5	..	30.0	..	..	0.10	0.06	0.07	0.38	0.23	..	0.10	0.11	..	0.30	..	..
Insecta																								
Plecoptera	40.0	11.8	..	..	..	..	..	..	..	..	..	70.0	1.70	0.12	..	..	..	..	..	..	..	..	..	3.60
Ephemeroptera	20.0	76.5	26.7	61.5	50.0	..	50.0	36.8	57.1	70.0	87.5	40.0	0.50	1.00	0.40	0.85	0.50	..	0.30	0.47	0.86	1.30	1.25	0.60
Odonata																								
Anisoptera	..	..	..	..	..	..	..	..	..	10.0	..	..	..	..	..	..	..	..	..	..	..	0.10	..	..
Trichoptera	10.0	17.6	20.0	7.7	4.5	..	..	..	..	..	25.0	..	0.10	0.18	0.20	0.15	0.05	..	..	..	..	..	.25	..
Coleoptera	10.0	..	..	..	4.5	..	..	..	..	10.0	..	..	0.10	..	..	..	0.05	..	..	..	..	0.10	..	..
Diptera																								
Chironomidae	70.0	64.7	100.0	92.3	45.5	..	20.0	15.8	14.3	10.0	12.5	100.0	7.20	2.12	12.00	2.23	1.41	..	0.20	0.21	0.43	0.10	0.50	5.70
Others	..	..	6.7	15.4	9.1	..	..	10.5	..	..	..	..	..	..	0.07	0.15	0.09	..	..	0.11	..	..	..	..

Fig. 11. — Hybrid *Etheostoma squamiceps* x *E. kennicotti.*

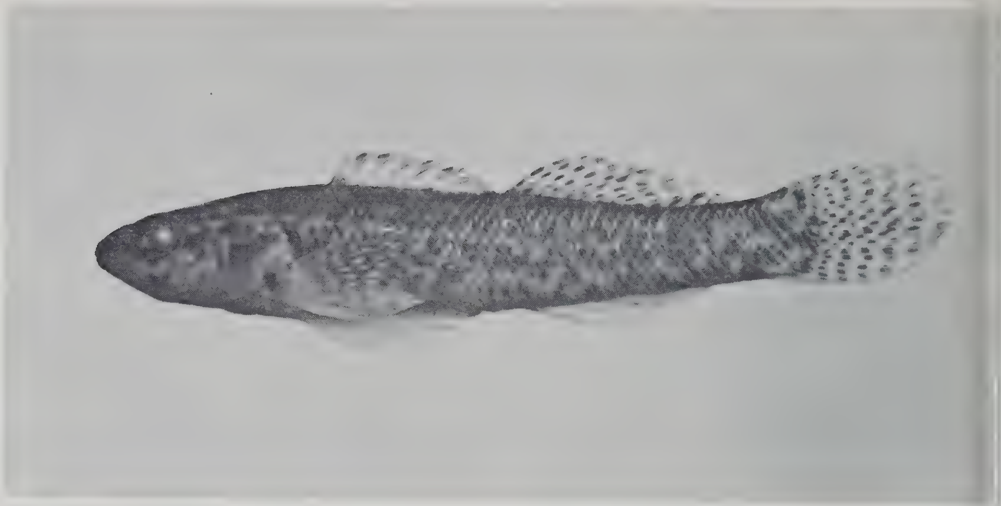

Table 10.—Summary of life-history information on Big Creek *Etheostoma kennicotti.*

Characteristic	Life-History Data
Principal habitat of adults	Slab pools
Principal habitat of young	Slab pools
Age at reaching sexual maturity	1 year
Age at first spawning	1 year
Size at reaching sexual maturity	Females about 30 mm; males about 35 mm
Sexual dimorphism	Adult males average larger, are more boldly patterned in spring, and ha longer fins and a deeper caudal peduncle; females have a larger nu ber of pored lateral-line scales
Breeding tubercles	Absent
Number of mature ova in preserved females	24–130
Description of egg in nest	2.1 mm in diameter, translucent, adhesive
Spawning period	From early April to late May
Spawning habitat	Slab pools
Spawning position	Both male and female inverted, usually head-to-tail
Nesting site	Underside of a slab stone
Number of eggs counted in nests	50–400
Egg guarding	Only by the male
Incubation period	145–150 hours at 19–23° C
Influence of sex on growth rate	By the third year males are significantly larger than females
Density	Up to 6.5 darters/m^2 in slab pools
Sex ratio among young	1.4 females : 1 male
Longevity	2+ years
Maximum size	54 mm standard length
Migrations	No obvious patterns
Territoriality	Extreme in breeding males; strong in nonbreeding males; occasional females
Principal diet	Aquatic insect immatures and crustaceans

LITERATURE CITED

Braasch, M. E., and P. W. Smith. 1967. The life history of the slough darter, *Etheostoma gracile* (Pisces, Percidae). Illinois Natural History Survey Biological Notes 58. 12 p.

Collette, B. B., and L. W. Knapp. 1966. Catalog of type specimens of the darters (Pisces, Percidae, Etheostomatini). U.S. National Museum Proceedings 119 (3550): 1–88.

Cross, F. B. 1967. Handbook of fishes of Kansas. Universit of Kansas Museum of Natural History Miscellaneo Publication 45. 357 p.

Forbes, S. A., and R. E. Richardson. [1908.] The fishes Illinois. Illinois State Laboratory of Natural Histor cxxxi + 357 p.

Jordan, D. S., and B. W. Evermann. 1896. The fishes North and Middle America. U.S. National Museum Bu letin (47):1–1240.

LAKE, C. T. 1936. The life history of the fan-tailed darter *Catonotus flabellaris flabellaris* (Rafinesque). American Midland Naturalist 17(5):816–830.

LEWIS, W. M. 1957. The fish population of a spring-fed stream system in southern Illinois. Illinois State Academy of Science Transactions 50:23–29.

MOORE, G. A. 1968. Fishes. Pages 21-165 *in* W. F. Blair, A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore, Vertebrates of the United States. 2nd ed. McGraw-Hill Book Company, New York.

PAGE, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps*, in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———, and P. W. SMITH. 1971. The life history of the slenderhead darter, *Percina phoxocephala*, in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes 74. 14 p.

PUTNAM, F. W. 1863. List of the fishes sent by the museum to different institutions, in exchange for other specimens, with annotations. Bulletin of the Museum of Comparative Zoology 1(1):2–16.

SMITH, R. J. F., and B. D. MURPHY. 1974. Functional morphology of the dorsal pad in fathead minnows (*Pimephales promelas* Rafinesque). American Fisheries Society Transactions 103(1):65–72.

WINN, H. E. 1958*a*. Observations on the reproductive habits of darters (Pisces-Percidae). American Midland Naturalist 59(1):190–212.

———. 1958*b*. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecological Monographs 28(2):155–191.

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The Nest Biology of the Bee *Andrena (Ptilandrena) erigeniae* Robertson (Hymenoptera: Andrenidae)

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The Nest Biology of the Bee *Andrena (Ptilandrena) erigeniae* Robertson (Hymenoptera: Andrenidae)

Lloyd R. Davis, Jr. and Wallace E. LaBerg

Detailed biological information on bees of the genus *Andrena* has been scarce (Linsley, MacSwain, & Smith 1952*b*; Michener 1953*a*; Linsley 1958) and for hundreds of species little or nothing is known. Also most of the observations on *Andrena* life histories have been conducted in an opportunistic fashion, largely because of the difficulty in locating nests and the expense and time involved in necessary traveling. Studies have been conducted on the researcher's lawn, in a path on a college campus, near the tent on a camping trip, or incidentally while studying something else. Although several good papers on *Andrena* biology are now extant (Malyshev 1936; Linsley & MacSwain 1959; Michener, Cross, Daly, Rettenmeyer, & Wille 1955; Hirashima 1962; Stephen 1966*a;* Thorp & Stage 1968; Thorp 1969; Rozen 1973) much remains to be done.

The aim of this work is to describe the biology of *Andrena* (*Ptilandrena*) *erigeniae* Robertson. The field work was carried out in Brownfield Woods, northeast of Urbana, Illinois. Laboratory work was done at the Illinois Natural History Survey and the Vivarium of the University of Illinois. The study began about April 1, 1974 and continued through the summer and early fall months of 1974.

At the outset of this study little was known of the biology of *A. erigeniae* or of other members of the subgenus *Ptilandrena,* a small group of solitary bees inhabiting the eastern deciduous forests. This subgenus has yet to be revised and thus an accurate listing of included species is not now possible. However, Mitchell (1960) lists *A. erigeniae* and the following species: *A. distans* Provancher (Robertson's *A. g-maculata*), *A. polemonii* Robertson, *A. krigiana* Robertson and *A. parakrigiana* Mitchell. LaBerge (1967) reduces *A. parakrigiana* to a synonym of *krigiana* and moves this species from *Ptilandrena* to the subgenus *Callandrena.* Therefore, only two species — *distans* and *polemonii* — remain in *Ptilandrena* in addition to *erigeniae.*

Robertson described *A. erigeniae* in 1891 and Mitchell (1960) gave us a more complete description of the species. It is a univoltine vernal bee found frequenting most eastern woodlands. It nests i the woods or along wooded margins where sprin beauty, *Claytonia virginica* Linnaeus, is abundan Robertson (1891) stated that he collected the bee o *Claytonia virginica, Erigenia bulbosa* (Michx.) Nut (harbinger-of-spring), and *Hydrophyllum appendicu latum* Michx. (waterleaf). Mitchell (1960) report only *Claytonia virginica* and *Erigenia bulbosa* as flora records. Three females of *erigeniae* were collected o *Collinsia verna* Nutt. (blue-eyed Mary) by John Mar lin at Carlinville, Illinois, May 3, 1971. Other flora records are *Isopyrum biternatum* (Raf.) T. & C (false rue anemone) on April 15, 16, and 18, 189 (Robertson, unpublished), and *Dicentra cucullari* (L.) Bernh. (dutchman's breeches), *Dentaria laciniat* Muhl. (cut-leaved toothwort) both at Carlinvill April 8, 1971 by John Marlin. Knerer & Atwoo (1964) reported *erigeniae* from Ontario, Canada, o *Claytonia* and *Prunus* based on less than six speci mens, the sexes of which were not noted. LaBerg collected a male of *erigeniae* on *Barbarea vulgari* R. Br. (yellow rocket) on April 18, 1974, 15 mile southeast of Winchester, Virginia. One specimer collected near Plummers Island, Maryland, April 12 1917 by J. C. Crawford was taken on *Veronic hederaefolia* L. (ivy-leaved speedwell). Pierce (1918 noted that a stylopized female of *erigeniae* (unverified) was collected at Plummers Island, Maryland March 29, 1915 by J. C. Crawford on *Erythroniun americanum* Ker. (yellow adder's-tongue).

Although *A. erigeniae* has occasionally been collected on a number of plant species, the female appear to be entirely restricted for pollen to *Claytoni virginica* (Fig. 15), which accounts for 91.8 percen of the floral records available for this study (28 specimens with floral data out of 456 examined — see Table 1). The range of *erigeniae* (Fig. 1) is largely coterminous with that of *Claytonia virginica.*

We are grateful to many people for help with various aspects of this project. Special thanks are due to the members of the staff of the Faunistics Section of the Illinois Natural History Survey; to Chris T. Maier, Douglas W. Schemske, and Kathleen A. Schemske, graduate students of the University of Illinois; and to Dr. S. Charles Kendeigh of the University of Illinois, Dr. Robert A. Evers, botanist of the Natural History Survey, and Dr. Charles D.

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COVER PHOTO: *Andrena erigeniae* sucking nectar from flower of *Claytonia.*

TABLE 1.—Floral records for *Andrena erigeniae.*

Plant	Males	Females	Total
Cruciferae:			
Barbarea vulgaris R. Br.	1	0	1
Dentaria laciniata Muhl.	1	0	1
Hydrophyllaceae:			
Hydrophyllum appendiculatum Michx.	2	0	2
Liliaceae:			
Erythronium americanum Ker.[a]	0	1	1
Papaveraceae:			
Dicentra cucullaria (L.) Bernh.	1	0	1
Portulacaceae:			
Claytonia virginica L.	72	188	260
Ranunculaceae:			
Isopyrum biternatum (Raf.) T. & G.	1	3	4
Rosaceae:			
Prunus sp.[b]	?	?	?
Scrophulariaceae:			
Veronica hederaefolia L.	0	1	1
Collinsia verna Nutt.	0	3	3
Umbelliferae:			
Erigenia bulbosa (Michx.) Nutt.	8	1	9
Totals (11 plants in 9 families):	*86*	*197*	*283*
Bees available without floral data:	38	135	173

[a] From Pierce (1918).
[b] From Knerer & Atwood (1964) (undetermined number of specimens).

Michener of the University of Kansas for their kind suggestions and helpful criticism.

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MATERIALS AND METHODS

Temperature readings were obtained from two centigrade thermometers, one hung from a hook on a tree over the nesting site and the other placed on the ground at the level of nest entrances. Both thermometers were partially shaded.

The bees were timed in their various activities with two stopwatches and a pocket watch. Plaster-of-Paris was poured into the nests and a small trowel and a microspatula used to excavate the nests. Small plastic sandwich bags were used to transport cells and contents to the laboratory. Kahle's solution was used to fix bee larvae and 70 percent alcohol was used to store the larvae after they had been fixed.

Pollen balls were frozen after being measured. Pollen was determined by microscopic examination of material mounted in glycerin jelly on slides made from known pollen sources. Such pollen slides were made from the pollen balls obtained from bee nests or from pollen washed off of the scopae of pinned bees (Thorp 1969).

Measurements were made with Helios dial-calipers and the ocular micrometer of an M5 Wild stereomicroscope. All measurements were either taken in millimeters or converted thereto.

Photographs were taken with a Nikkormat FTN (35 mm) camera with bellows and f3.5 55 mm Auto Micro Nikkor lens. Kodak Panatomic-X and Ektachrome-X film were used. Drawings were made with the use of the M5 Wild microscope and drawing attachment.

Distributional data were obtained from pinned specimens belonging to various major collections, and length of life of adults after emergence was determined from pinned specimens, from personal observations, and the observations of Douglas W. Schemske.

Nests were marked with two large brass paper fasteners, one on each of opposite sides of the entrance. Forty-five of the nests so marked had color coded markers so that the nest could be referred to easily and so that the bee using the nest could be marked correspondingly. Because of the size of the bee, combinations of more than two colors were found to be impractical. The color code was a simple four-way combination of any two of five colors: red, green, blue, yellow, and white. For example, the codes green/white, $\frac{\text{green}}{\text{white}}$, white/green, and $\frac{\text{white}}{\text{green}}$ represent four different nests. Thus by rotating the fasteners 90 degrees with each new nest, four nests could be marked individually while using only two colors. Forty nests were marked in this manner. Other nests located in the area were coded consecutively in a particular color, e.g., red 1, red 2, or blue 17.

Occasionally a glass vial was used as a trap, placed over the nest opening immediately after the bee entered. More frequently the bee was caught by covering the hole with a small screen cone (Linsley, MacSwain, & Smith 1952*a*; Osgood, unpublished). The bees were marked to agree with their respective nests and were released as soon as possible to avoid damage to the insects from excessive handling.

For morphological studies the bee larvae were

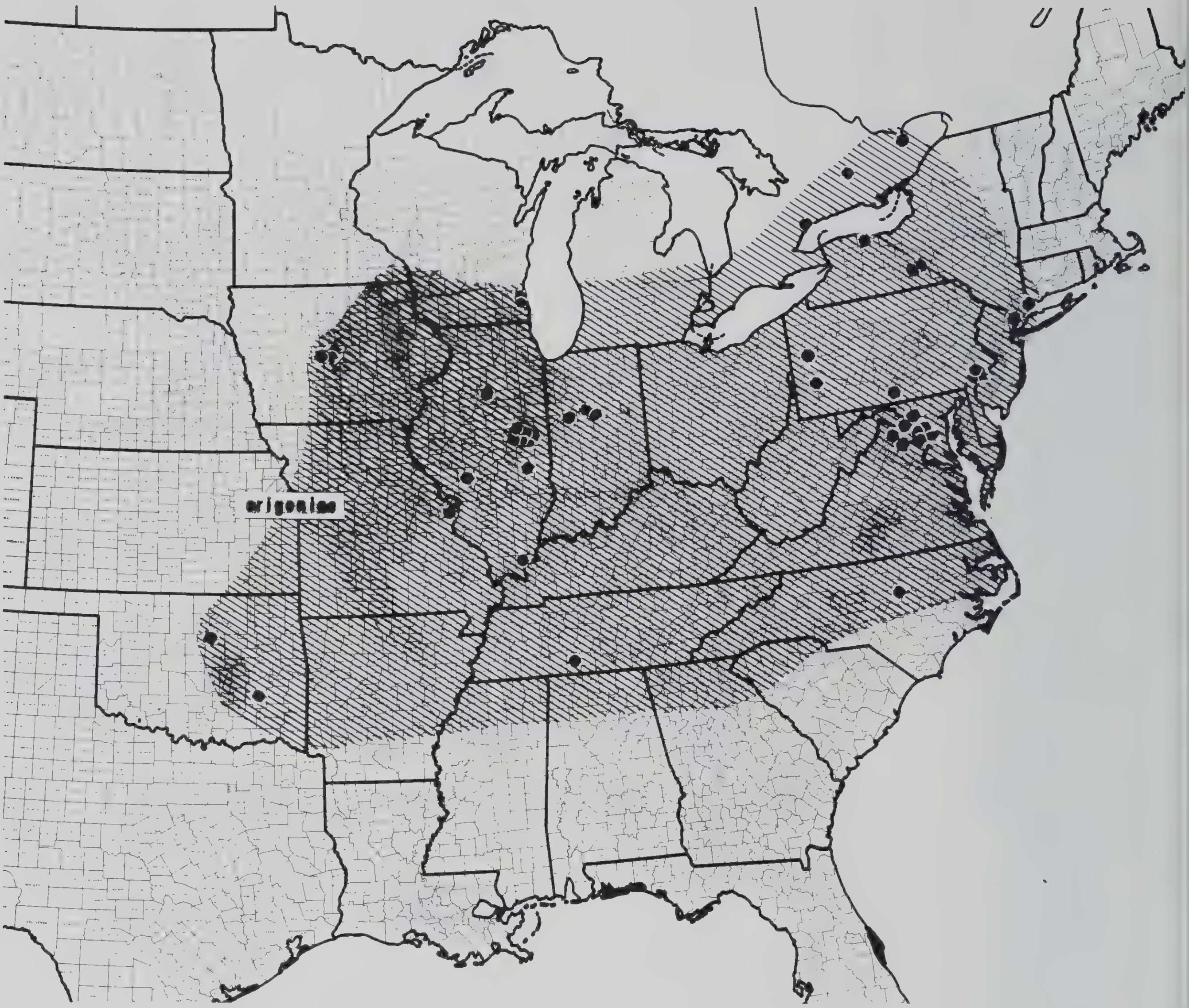

Fig. 1.—Map showing the known distribution of *Andrena* (*Ptilandrena*) *erigeniae* Robertson.

cleared in lactophenol and stained with acid Fuchsin. A compound microscope was necessary to examine details of the spiracles.

DESCRIPTION OF NEST SITE

The nests were located in Brownfield Woods, a rectangular 60-acre remnant of a forested area known as the Big Grove that once occupied a 10-square-mile area in a bend of the Salt Fork River, northeast of Urbana, Champaign County, Illinois (Boggess & Bailey 1964). At the southeast corner of section 34 of T20W, R9E, the woods is located just east of the the now defunct town of Augerville and was at one time known as the Augerville Woods, a frequently recorded locality at the turn of the century. The woods is now owned by the University of Illinois, has been surveyed and soil mapped, and has numbered stakes every 50 m which conveniently locate any section of particular interest.

Bailey (1962) gave the soil characteristics for a small area of the woods. The soil was found to consist of two main types: Birbeck silt loam on 2-4 percent slopes and Sabina silt loam on 0-2 percent slopes. The nest site studied here is located in the later soil type. Information on profiles of this soil type may be obtained from Alexander & Paschke (1972).

The nest site was a low ridge of soil located about 21 m from the forest edge (Fig. 2). The primary area in which nests were located was divided by a depression that frequently retained water after it rained. Thus the site contained two isolated nesting areas about 3 m apart. The larger area ran along the

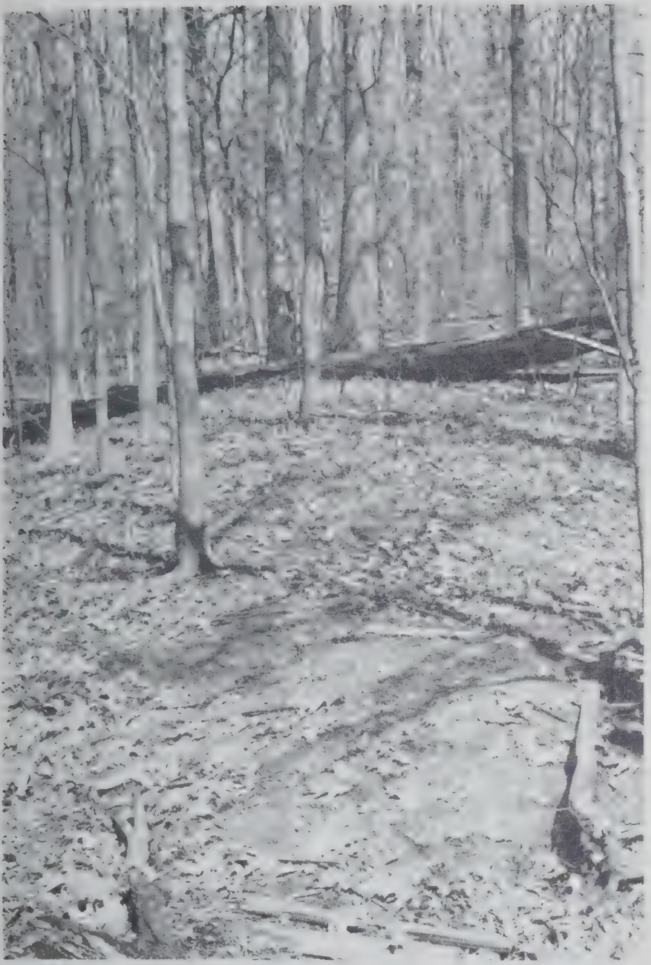

Fig. 2.—View of the larger section of the nesting area looking to the east (April 12, 1974).

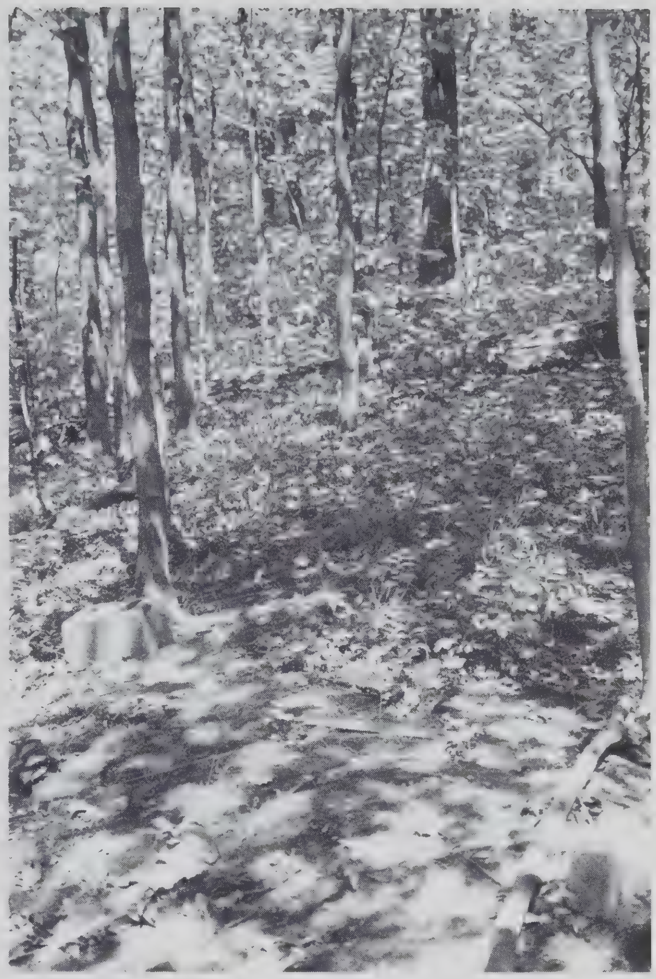

Fig. 3.—View of the larger section of the nesting area looking to the east (May 10. 1974). Note the change in the canopy between Fig. 2 and 3.

ridge mentioned above for 12 m and was about 3 m wide (Fig. 2 and 3). The other area was only 3 m long and 2 m wide. The larger area of the nest site was partially covered by fallen leaves, sticks, and patches of moss (Fig. 4). *Claytonia virginica, Dentaria laciniata, Dicentra cucullaria,* and *Viola* sp. grew on both areas. Seedling sugar maple trees (*Acer saccharum* Marsh) also were found on the sites (Fig. 3). The smaller area was without the moss patches of the larger site but was otherwise very similar. A few additional nests were also located along the margin of the woods in a dense patch of *Erythronium* sp.

Osgood (1972) found that the amount of organic matter in the 0_2 horizon was the most important soil characteristic in determining whether or not a particular area may be expected to have solitary bee nests. Areas with high levels of organic matter in the 0_2 horizon had significantly fewer nests. The soil types found in Brownfield Woods average about 2.0 percent in surface organic matter (Alexander & Paschke 1972). This is even lower than the 8.4 percent found by Osgood (1972) for bee nesting areas in the blueberry barrens of Maine.

It was also noted by Osgood (1972) that chosen nesting sites have sparse to moderate plant growth on soils that are well drained with a good surface flow. These characteristics seem to fit the nesting site of *A. erigeniae*. Burrows of *erigeniae* were about 15 cm deep and the water level in the site was sometimes only 8 cm below the deepest cell. Champaign County gets an average of 9 cm of rain for the month of April (Page 1949). With the frequent rainfall during the flight period of *erigeniae*, it is likely that one of the most important factors in the choice of a nest site is the elevation of drainage of the soil. Rau (1935) suggested that the most important factor affecting Missouri populations of *A. erythrogaster* (Ashmead) was the amount of rainfall for the month of April and the resulting level of the subsurface water table.

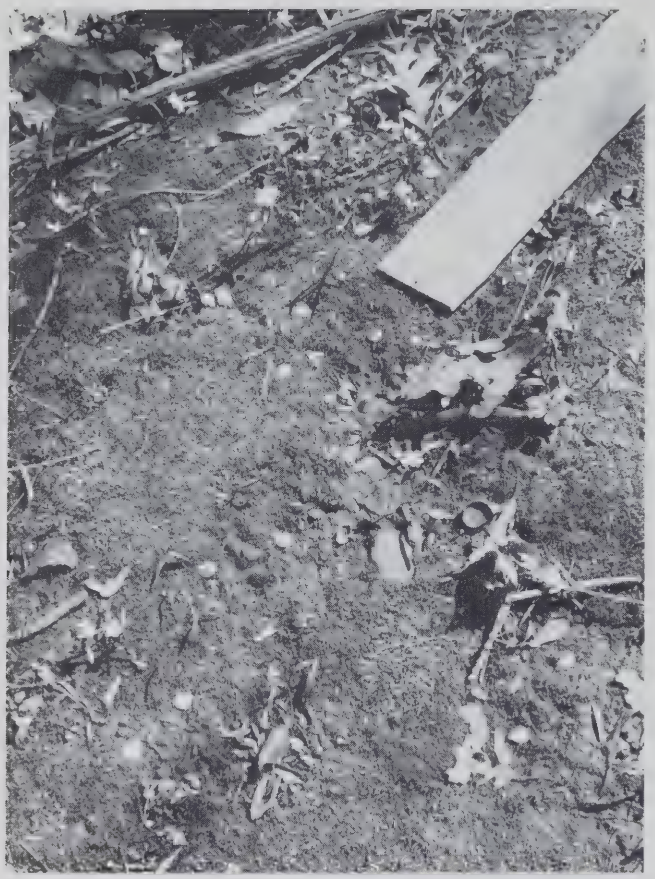

Fig. 4.—View of nest site showing nest markers and the presence of *Claytonia virginica* and moss. Note the sparseness of leafy vegetation.

PRENESTING BEHAVIOR

Emergence, premating, and mating behavior were not observed. Michener & Rettenmeyer (1956) found that collecting records indicated a proterandry in *A. erythronii* Robertson that did not actually exist. They discovered that *erythronii* usually mated at the nesting site and the females disappeared into the ground soon after mating to begin digging their nests. This left the males as the principal specimens available to collectors. Both sexes of *A. erigeniae* are equally represented in collections taken early in the season. Robertson (1930) found males from April 5 to May 3 and females from March 25 to May 14. Thus, *erigeniae* appears to lack the proterandrous condition reported for some other andrenids. Data from collecting records indicate that mating of *erigeniae* probably takes place on flowers of *Claytonia virginica*.

LOCATION OF NESTS

The nests of *A. erigeniae* were first found under leaves and this was accomplished by following a pollen-carrying bee. When the leaf was overturned, a nest entrance was often exposed. This method can be used to locate many other vernal *Andrena* nests in wooded areas (Stephen, Bohart, & Torchio 1969; LaBerge, unpublished data). Although many nests are found beneath leaves, leaf litter is not necessarily an indication of nest sites. In many areas of Brownfield Woods that had leaf litter closely resembling that at the nest sites no nests were found. In general, no nests were found where the leaf litter was thick enough to keep the ground beneath constantly wet.

Nesting beneath a thin layer of fallen leaves probably serves primarily to protect the nest from heavy spring rains that commonly fill in the burrows of unprotected nests. The leaves may also protect the nest somewhat from predators and parasites, functioning in some way in nest recognition by the bees. Recognition of its nest by the bee probably depends on a combination of both olfactory and visual cues. Dependence upon some sort of cue is shown by the observation on April 10, 1974 that a female twice tried unsuccessfully to locate her nest from which the covering and surrounding leaves had been removed. Only after the third attempt did the bee succeed in finding the entrance.

With respect to nesting, *A. erigeniae* appears to be gregarious (Fig. 4). *A. carlini* Cockerell, found nesting in the same area, seems, on the other hand, to be rather solitary. The density of nests of *erigeniae* ranged from 1 to 21 per m^2, whereas that of *carlini* ranged from one to three nests per meter. This may indicate only that *carlini* prefers another soil or cover type for nesting aggregations. Atwood (1933) records dozens of nests of *carlini*, "close together," in northeastern Canada.

Possible reasons for gregarious nesting in solitary bees have been proposed (Perkins 1919; Michener & Rettenmeyer 1956; Stephen 1966*a*). No new light has been shed on this question during the course of this investigation. However, it would be interesting to capture and mark all emerging bees from a particular nest site and determine exactly what percentage of the population disperses and whether the dispersing segment is from a group of relatively late emergers as compared to the normal range of emergence times. There would seem to be obvious selective advantage for nesting in the same area where the parent had nested. Perhaps the earliest bees to emerge nest in the most suitable sites of the immediate area. The activity of these bees or the presence of old nests in the site may cause the area to be attractive (by means of olfactory stimuli) to later emerging bees until, at a certain density, the area becomes saturated with nests, at which time subsequently emerging bees would be forced to disperse. Such dispersal, triggered by whatever mechanism, seems to be almost a necessity for the survival of the species because of the possible deleterious effects of a build-up in populations of inquilines, parasites, nd predators (or disease) in a concentrated nesting ggregation.

NEST CONSTRUCTION

Digging by female bees apparently begins soon fter emergence. Nests of *A. erigeniae* were found irst on April 3, 1974, although adult bees were ob- erved above ground and collected on March 31, 974 by Douglas W. Schemske. Digging may begin orizontally on the side of a small raised lump of soil, r, more typically, vertically under a leaf or stick, n bare soil, on or through moss (Fig. 5), or in a epression already present at the site. One female bserved searching for an appropriate nest site on April 13, 1974 at about noon behaved similarly to A. *erythronii* described by Michener & Rettenmeyer (1956). This bee dug a partial hole in one area and hen abandoned it to dig a few centimeters away. Once the final site was chosen, the bee continued to ig as long as it was observed.

While digging a nest, the female enters the hole head first and scrapes off small, irregularly shaped and sized particles of dirt with her mandibles and prothoracic legs. As the digging progresses the bee works in a circle around the perimeter of the nest in either a clockwise or counterclockwise direction. As small particles of dirt are scraped away, they are collected by the legs and passed back to the metathoracic legs whereby they are pushed out of the burrow as the bee backs out. The abdomen is also used to flick out these small pellets of dirt and to push them away from the nest opening. Apparently the details of the digging process are quite similar for many species of *Andrena*. Sivik (1954) describes essentially the same process for *A. macra* Mitchell. Michener & Rettenmeyer (1956) offer similar details for *A. erythronii*.

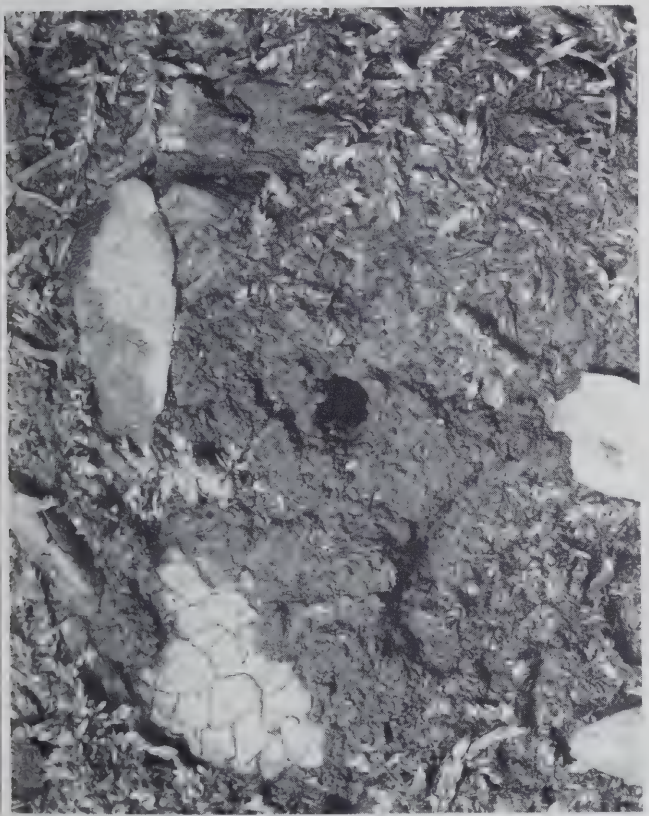

Fig. 5.—Typical nest entrance (center of photograph) of *Andrena erigeniae*. Note that the tumulus has been washed away by rain.

As a result of bringing this soil to the surface, a small, usually circular or oval pile of particles called a tumulus collects around the nest entrance. The tumuli vary in size from 1.5 to 6 cm in diameter and from 0.25 to 1.5 cm in height (12 measurements).

At times during nest construction, the dirt particles may partially obscure the nest entrance. This condition is temporary and may last only for the period of time it takes the bee to bring up another load of soil particles. The tumulus may sometimes be helpful in locating new nests, as its edges are occasionally visible beneath leaves. The short-lived tumuli are usually completely obliterated by the first rain after construction, leaving only the entrance hole to mark the presence of the nest (Fig. 5 and 6).

A. erigeniae, unlike *A. erythronii* (Michener & Rettenmeyer 1956), leaves its burrow open during the foraging period of the day. However, after making the last pollen-collecting trip of the day, the bee normally remained in the nest after unloading her pollen, and after a few minutes could be observed bringing up soil particles to form a small plug about a centimeter below the surface. Thus, the nest was plugged with the bee inside. The soil from such plugs

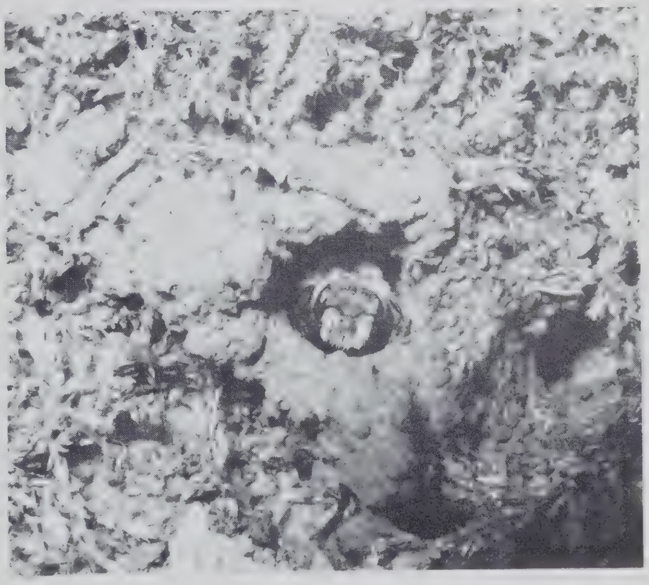

Fig 6.—Female *Andrena erigeniae* in typical pose at the nest entrance.

may have come from the walls of the main shaft of the burrow, or, more likely, may have come from a new cell being constructed in the burrow. Linsley & MacSwain (1959) noted that *A. complexa* and *A. suavis* (both belonging to the *Geandrena* LaBerge, 1964) formed similar nest plugs at the end of daily foraging activity. This behavior has also been observed for the *Diandrena* by Thorp (1969). *A. complexa* was found to make about four collecting trips to complete a 50-mm pollen ball (Linsley & MacSwain 1959). Occasionally *erigeniae* made five trips a day but more frequently made only four or less, the latter especially if weather conditions became limiting. Thus, if these four or five trips are all that are required to complete a pollen ball, the plug is apt to be formed from soil removed during the construction of a new cell. The following day the plug was removed before the onset of foraging activity.

Nests of *A. erigeniae* were found to be 15 cm or less in depth (Fig. 7). The main shaft of the burrow was vertical or nearly so, and essentially straight except for necessary alterations in heading to avoid obstacles such as roots and small stones. At a dept of from 8 to 15 cm the burrow usually made a shar change in direction and proceeded horizontally o downwards for from 3 to 6 cm. In general outlin (Fig. 8–11), the nests were quite similar to tha drawn by Thorp (1969) for the *Diandrena.*

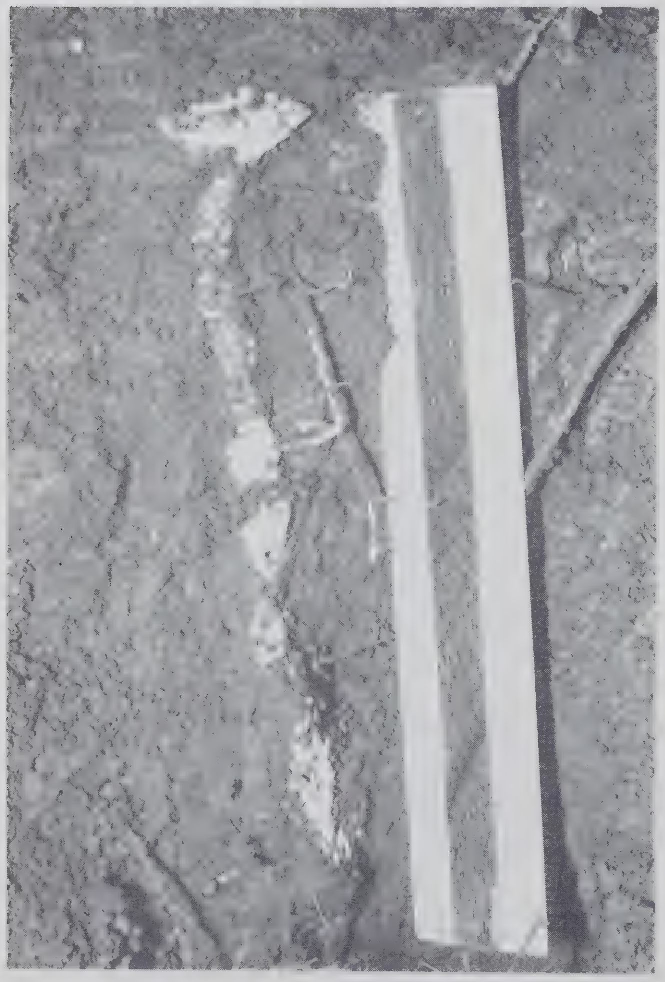

Fig. 7.—Excavated nest (plaster-poured) of *Andrena erigeniae* showing the position of one cell at the lower left.

Two observations were made of *A. erigeniae* fillin in nests prior to abandonment (Fig. 12). The be enlarged the opening around the entrance to approximately twice its diameter by breaking off smal particles of soil with its mandibles. The soil wa packed into the nest lumen until the opening wa entirely obstructed. The bee then walked away t rest on a leaf and, after a few minutes, flew away.

The main shaft of the burrow of *A. erigeniae* i simple and unbranched. The number of cells foun in a nest varies from 3 to 14, but is commonl 6 to 8. Laterals leading to cells are dug along th main shaft of the burrow on all sides and exten from 2 to 5 cm from the main shaft. Cells wer found from 6.5 to 15 cm below the surface. Thi would put them below the frost level except o very cold years. Lateral connectives leading fron the main shaft of the burrow to the cells are ope only during actual provisioning. There was no evidence that the bees closed the laterals between pollen

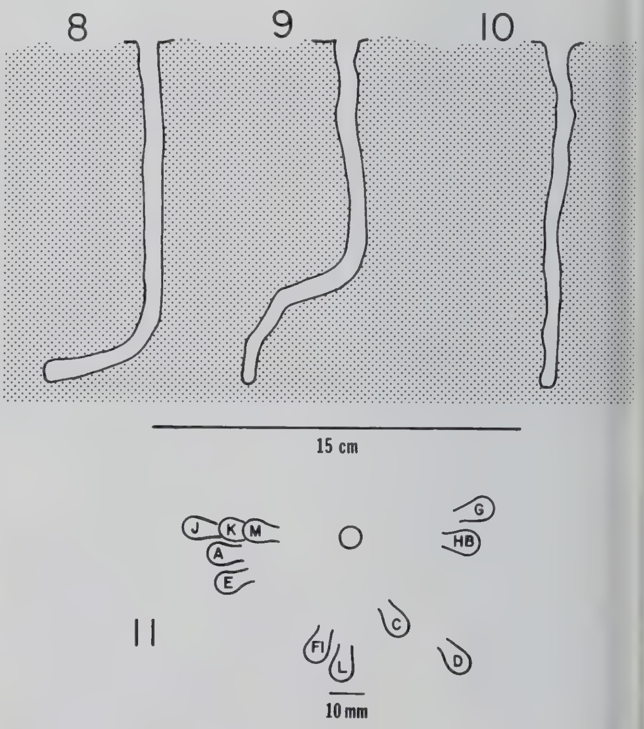

Fig. 8–11.—Nest architecture of *Andrena erigeniae* nests 8–10.—Lateral views of three nests, the first typical, th next two variations. 11.—Diagram of the relative position of the cells in a single nest as seen from dorsal view Letters indicate relative depth of each cell with A indicatin the shallowest and oldest cell. Two letters indicate tw cells, one above the other.

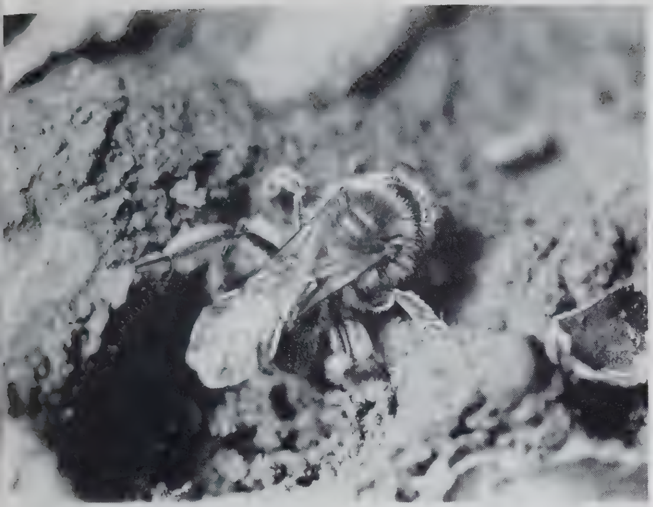

Fig. 12.—Female *Andrena erigeniae* filling in nest prior to abandonment (May 10, 1974).

collecting trips as do *A. accepta* (Rozen 1973). Upon completion of the pollen ball and subsequent oviposition, the laterals are packed full of loose dirt. It was not possible to trace the path of a lateral to the main shaft. This made the identity of certain cells doubtful when the exposed nest was near other nests. In general, the direction in which the cell plug pointed was used to determine the relationship of particular cells to a particular burrow.

In nests dug before the bee had completed provisioning, the incomplete cell was the deepest and was located at the end of the burrow. No nests were found to have more than one incomplete cell. In nests dug later in the season, the cells deepest in the ground contained pollen balls that had been only partially consumed. Cells closer to the surface in these same nests contained larvae that had completely eaten their provisions. Therefore, unlike *A. viburnella* (Stephen 1966*a*), *A. erigeniae* is a progressive nest builder and constructs horizontal rather than vertical cells.

From our observations, nesting took place from the last week of March until about the second week of May. Robertson (1929) lists the flight period as 50 days, or from 10 days after the start of blooming of *Claytonia virginica* to 10 days before the end of the blooming period.

Variability in the time when nesting activity began is thought to be mainly the result of a normal range in emergence of females, but possibly some late nests are actually the second nests of some bees. Marking procedures did not help solve this problem, as the paint was worn off of most bees too soon. However, while marked, none were observed going to more than one nest.

Nest diameters varied within individual nests. Average nest diameters ranged from 4.75±0.06 mm (N=12) to 6.87±0.36 mm (N=11) for 10 nests measured. An overall average burrow diameter was 5.70±0.09 mm (N=134) for 13 nests measured.

The construction of cells was similar to that described by Michener & Rettenmeyer (1956) for *A. erythronii.* Cells were apparently constructed in a small cavity created by the bee and lined with a layer of packed soil about 0.5 mm thick. This lining was covered with a very thin layer of material that probably was related to silk in composition. This lining waterproofs the cell (Thorp 1969; Rozen 1968). The surface of the lining appeared very shiny and was covered by scattered droplets of liquid (Fig. 13). It was not determined whether these droplets were water or nectar or were of some other composition. An attempt to run a simple test on the contents of some of these droplets failed because of their very small size and the necessity to relocate them to a glass plate for the test. It is reported in the literature (although untested) that these droplets are nectar (Malyshev 1936; Michener & Rettenmeyer 1956). Linsley & MacSwain (1959) observed similar droplets in the cells of *A. complexa* and *A. suavis.*

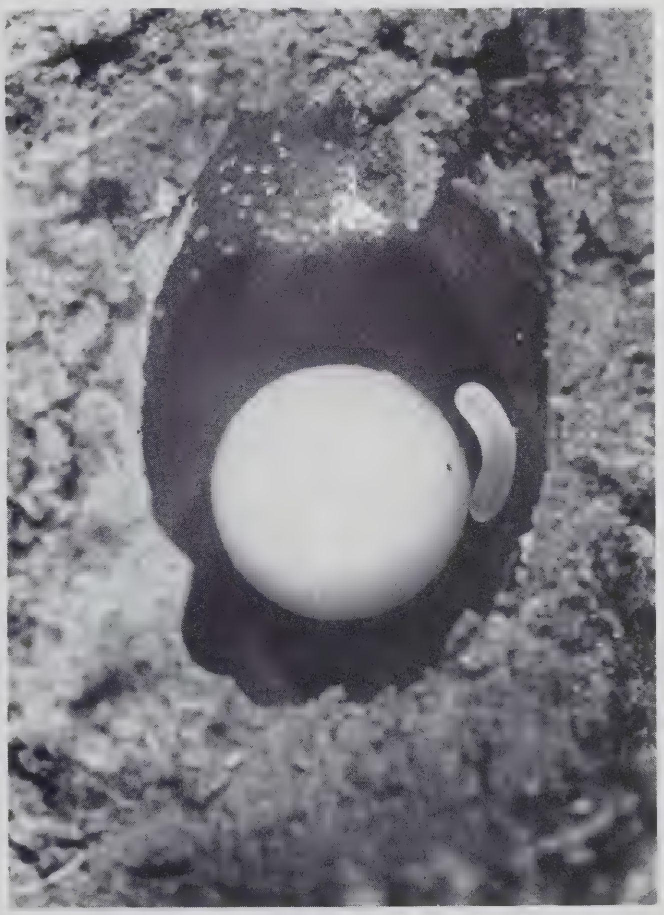

Fig. 13.—Cell, pollen ball, and egg of *Andrena erigeniae.* Note the small droplets of liquid on the cell wall, and that the egg touches the pollen ball on one end only.

BEHAVIOR OF BEES AT THE NESTING SITE

Adult females of *A. erigeniae* take 33.29±2.28 minutes (N=63) to make a pollen-collecting trip. Bees often waited near the entrance of the nest after unloading their pollen. Because of this, the time spent in the burrow can be divided into two measurable categories. One is the time from entering the burrow until the bee returns to the top (time required to unload the pollen) and the second is the total time spent in the nest before the next trip. The average time spent unloading pollen was 5.16±0.12 minutes (N=96), while the average time in the nest between trips was 7.54±0.56 minutes (N=65).

While in the nest the bee often stayed just below the surface or with only the head and thorax exposed (Fig. 6) and sudden movements by the observer at such times caused the bee to retreat by backing down the burrow. Most bees produced a faint buzzing sound when disturbed in this manner. After a few minutes the bee would reappear at the surface. Aside from bees digging nests or retreating from the observer, no bees were ever seen backing into or out of nests. One bee which had a vertical nest opening was observed to come to the surface on the side of the burrow that became the top of the vertical entryway. Thus when it reached the entrance it was upside down. It crawled around the entrance until it was right side up before flying.

Some bees flew off directly from the nest entrance. Others, especially on cooler days, crawled out of the nest slowly and sat on a nearby leaf or some other object before leaving. Bees bringing in loads of pollen showed a similar range of behavior. Linsley, MacSwain & Smith (1955) found that *A. mojavensis* Linsley & MacSwain, *A. deserticola* Timberlake, and *A. oenotherae* Timberlake usually landed directly at the nest entrance. On the other hand, Michener & Rettenmeyer (1956) noted that *A. erythronii* only rarely flew directly to the nest. Behavior of *A. erigeniae* was variable in this regard. Some bees landed practically on the rim of the nest, paused a moment, then entered. Others, again especially on cold days, landed sometimes as much as a meter from the nest and either walked to it or rested on a leaf for a while and then made a series of short flights to the nest. Bees almost always paused momentarily before entering or leaving the nest. During this pause it was very easy to frighten the bee. If the bee was about to enter the nest, it would fly away and return after a minute or so. One bee was frightened off four times in succession, three times by movements of the observer and once by a Syrphid fly hovering over the nest site.

An occasional bee left the nest and returned with no pollen. This was more common before April 15. One such bee left its burrow and was gone for 72 minutes before returning without any pollen. When a bee returned without pollen it paused momentarily at the entrance, entered, and returned to the surface in less than a minute (usually 40–50 seconds).

On cold days or days when the sky was dark and overcast the bees remained at the entrance of their burrows for long periods. Heavy rain prevented flight but both *A. carlini* and *A. erigeniae* were observed in flight during a light shower of rain.

Like *A. erythronii* (Michener & Rettenmeyer 1956) *A. erigeniae* did not exhibit aggressive behavior toward other bees. The observer placed a Nabid bug into the nest of one bee while the bee was present to see if any active defense of the nest could be observed. There was no indication of a struggle but the bee remained out of sight in the nest for the rest of the afternoon. The females of *erigeniae* are unable to sting so it would appear that their best strategy would be avoidance tactics rather than aggressive defense of the nest.

Although the nests of other species of bees were not abundant, at least two other species of *Andrena* (*carlini* Cockerell and *nasonii* Robertson) and one species of *Lasioglossum* were observed nesting in the *erigeniae* nesting sites.

PROVISIONING

Pollen collected by *A. erigeniae* is entirely that of *Claytonia virginica*. The pollen balls were spherical, pink, and moist. The color often changed to pale yellow after being exposed to air or after being partially consumed by either the larval bee or an inquiline. The pollen balls ranged in size from 3.2 by 3.35 mm to 4.3 by 4.6 mm in the two opposite diameters. The average size was 3.81±0.83 mm by 3.99±0.091 mm (N=24). This is smaller than measurements reported for *A. erythronii*, a larger bee, by Michener & Rettenmeyer (1956). Linsley & MacSwain (1959) gave the weight of the pollen ball of *A. complexa* as 0.05 g. Pollen balls of *erigeniae* ranged from 0.017 to 0.057 g with an average of 0.037±0.0022 g (N=26). The incomplete pollen ball in Fig. 14 weighed 0.0095 g. A remarkable variation existed in the size of pollen balls from a single nest. For example, one nest contained six pollen balls that weighed: 0.057, 0.028, 0.021, 0.025, 0.035, and 0.042 g.

Temperature and the opening of *Claytonia* flowers apparently set the early limits to daily foraging behavior of *A. erigeniae*. No bees were observed bringing in pollen loads before 10:00 a.m. (N=204). The end of daily foraging was probably determined by the completion of a cell (Linsley & MacSwain 1959), but may have been caused by dropping temperatures, lowering of light intensity, or rain. It is suggested that the completion of the pollen ball may be the primary reason for the end of pollen-

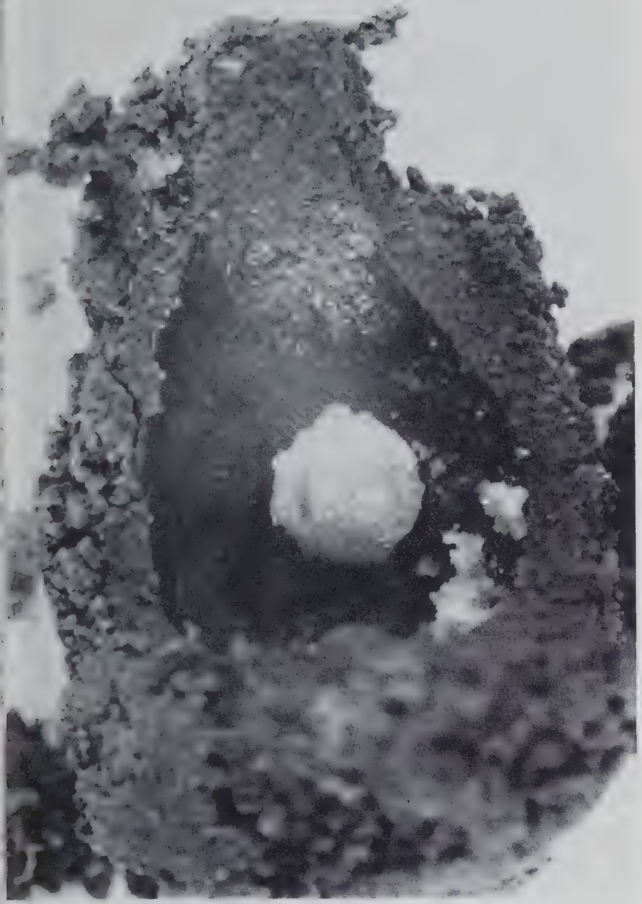

Fig. 14.—Incomplete pollen ball of *Andrena erigeniae*. Note the rough surface of the pollen ball.

ollecting for the day. This is because most bees eemed to finish foraging between noon and about :30 p.m. (N=29) when it was still light and often uite warm. Pollen availability may also play a part n this. By midafternoon most of the available *Clayonia* pollen would probably be gone, so that at a ertain point a bee would find the energy expended o collect a load of pollen the limiting factor. Data n the length of pollen-collecting trips indicated that he first and last trips of the day were often the ongest for an individual bee.

Time expended per trip in collecting pollen varied rom 10 to 92 minutes. Michener & Rettenmeyer 1956) found that trips for *A. erythronii* varied from 7 to 235 minutes. Stephen (1966*a*) reported the nean trip length for *A. viburnella* as 26 minutes (from range of 18–52 minutes) and suggested that the lifference between the times for *erythronii* and *iburnella* was because *erythronii* was oligolectic and *iburnella* was polylectic in foraging habits. Although he mean time spent collecting pollen was longer or *A. erigeniae* (about 33 minutes) than for *viurnella*, Stephen's explanation may not be correct. Generalizations about the foraging times with respect to floral constancy are entirely unreliable when generalizations are based solely on the behavior of locally studied populations. This is a consequence of the range of variability within a species of bee and between various populations of that species along with an obvious variability in the availability of proper nesting site locations. In fact, *erythronii* (Michener & Rettenmeyer 1956) foraged much earlier in the season than either *erigeniae* or *viburnella* (Stephen 1966*a*). Thus colder weather may have forced the bees to make more frequent rest stops between flower visits. Such activity has been observed for *erigeniae* on cold days. Contrary to the assumption of Stephen (1966*a*) an oliogolectic bee may at times find suitable nest sites directly among the host plants and require only very short trips to complete a pollen load.

Time spent in the nest between trips by *A. erigeniae* averaged about 7.5 minutes from a range of 4–31 minutes. Michener & Rettenmeyer (1956) observed a range of 17–88 minutes for *A. erythronii*. Stephen (1966*a*) observed a range of 6.5–33 minutes for *A. viburnella*. He attributed the difference between *viburnella* and *erythronii* to the fact that *erythronii* fashions a pollen ball while *viburnella* does not. *A. erigeniae* rolls its provisions into a ball very much like that of *erythronii;* therefore, it is unlikely that the time differences noted above are due to the particular difference in behavior noted by Stephen. The difference may more likely arise from the lower temperatures that characterize the earlier foraging of *erythronii*, if any difference other than the bees being of different species is to be accounted for.

As previously mentioned, pollen collected by *A. erigeniae* was fashioned into a largely spherical ball. Michener & Rettenmeyer (1956) noted that *A. erythronii* worked its pollen into a ball as it was brought into the nest. Incomplete, smaller balls were found to be drier and less smooth than completed balls. Linsley & MacSwain (1959) have noted the same sort of behavior for *A. complexa* and *A. suavis*. The pollen balls were formed by *erigeniae* in a similar manner (Fig. 13 and 14).

Very little quantitative observational data were obtained of bees actually gathering pollen. However, many *A. erigeniae* were seen visiting *Claytonia virginica* for both pollen and nectar. In gathering pollen, the bee encircled the stamens with its legs and bunched them together in the center of the flower (Fig. 15). The bee usually moved around the flower in a circle during this procedure. Pollen was thereby rubbed from the anthers onto the bee's body and legs and moved back to the scopae. Visits to flowers usually lasted only a few seconds. Two bees collecting pollen from *Claytonia virginica* on May 7, 1974, were observed to remain on the flower for 10.5 and 12.5

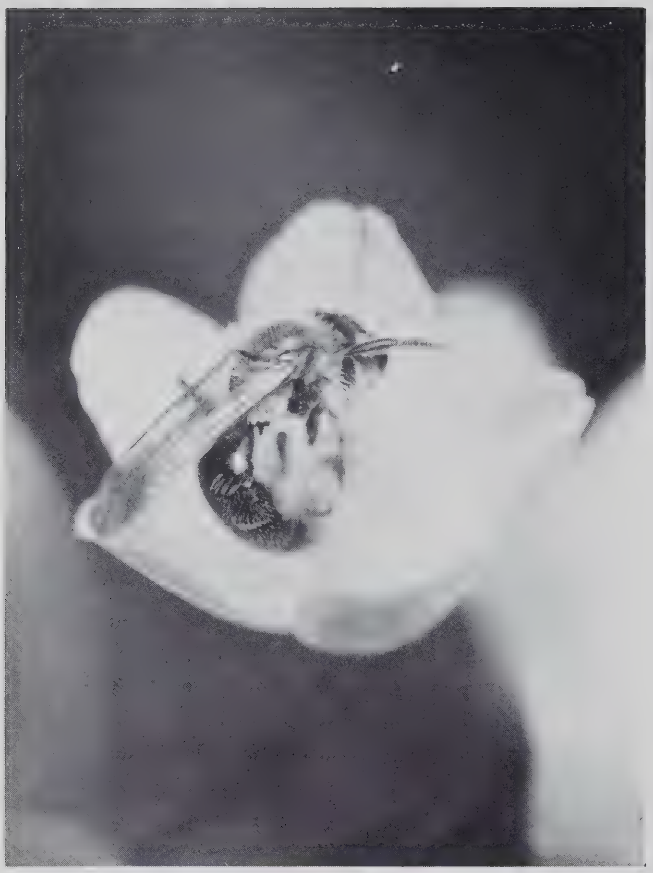

Fig. 15.—Female of *Andrena erigeniae* collecting pollen from *Claytonia virginica.*

seconds. Another bee stayed on a flower for 10.7 seconds drinking nectar.

As discussed above, on cool days a bee often spent a lot of time resting on leaves. A bee observed on May 7, 1974 drank nectar from one flower, crawled off to a nearby leaf, then visited three flowers, and flew to another leaf. Another bee was observed resting on a leaf for 49 seconds, spent 5 seconds on a flower, fell off, rested 64 seconds, visited another flower, and crawled back onto the first flower.

As the flight period of *A. erigeniae* progressed during May, the tree canopy gradually closed. *Claytonia virginica* was noted by Schemske (personal communication) to set seed rapidly as the light intensity under the canopy decreased. By the last of April only isolated patches of *Claytonia virginica* were still available to the bees for pollen. By the middle of May the plant was no longer in flower in the woods.

DEVELOPMENTAL OBSERVATIONS

A. erigeniae in our study area probably began nesting activities in 1974 about, or shortly before, March 31. Nests dug previous to and on May 10 contained only eggs. Nests dug on May 11 and 15 contained first instar bee larvae about the same si as the eggs (Fig. 16). On May 28 a nest was du that contained some large bee larvae that had co sumed about one-half to three-quarters of their polle balls. Other larvae in this same nest had complete eaten their pollen except for a few grains stuck their ventral surfaces. Nests dug on July 3 containe only postdefecating larvae.

Feeding of the larva produced a small pit in th pollen ball immediately beneath the head of the larv The pollen was gradually encircled as the larva gre until finally only a small amount remained on th ventral surface of the larva. Larvae defecated on th distal surface of the cell wall. The feces formed yellowish mass that contained the empty shells pollen grains.

All species of *Andrena* thus far studied overwint as adults in the cells of their nests (Michener & Rette meyer 1956). *Andrena* do not spin a cocoon whe they pupate (Stephen, Bohart & Torchio 1969). Pup tion takes place in late summer and adulthood reached sometime in the fall (Thorp & Stage 1968 *A. erigeniae* were found to be in pupal stage August 12 and some of the pupae had fully forme

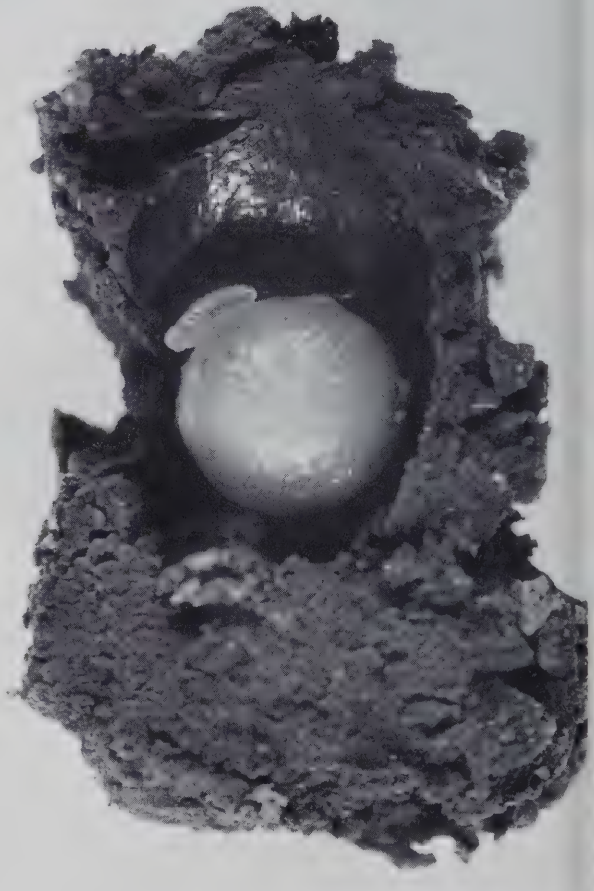

Fig. 16.—Newly hatched larva of *Andrena erigeni* resting on its pollen ball.

nd almost fully colored adult integument beneath e pupal integument. It is evident from this that *igeniae,* like other *Andrena,* does not spin a cocoon nd overwinters in the cell as an adult.

DESCRIPTION OF EGG

The egg of *A. erigeniae* was located on the top of e pollen ball with only the distal end (relative to e cell plug) touching the pollen (Fig. 13). This slightly different from the observations made for ther species of *Andrena.* The eggs of *A. erythronii* Michener & Rettenmeyer 1956), *A. suavis* and *A. mplexa* (Linsley & MacSwain 1959), and *A. accepta* Rozen 1973) touch the pollen ball at both ends. was observed that the egg readily stuck to the ollen ball if contact was made between the two. lmost all *erigeniae* eggs were attached at both ends fter being transported to the laboratory at which me some eggs were found lying flat against the ollen ball, as figured for *erythronii* (Michener & ettenmeyer 1956).

The chorion of the egg was very thin and delicate. s a result, many eggs were broken before they could e measured. Eggs of *A. erigeniae* were white and lightly bowed, much like those described for *A. lacida* by Thorp & Stage (1968). The egg measured .15±0.073 mm (N=13) in length and 0.51±0.015 m (N=13) in diameter. This is roughly similar to he dimensions reported for several other *Andrena* Michener & Rettenmeyer 1956; Hirashima 1962; ozen 1973). *A. rhodotricha* Linsley has an egg 3 mm n length and less than 1 mm wide (MacSwain 1945). Thorp & Stage (1968) reported the egg of *placida* as .4–2.7 mm by 0.57–0.75 mm.

DESCRIPTION OF POSTDEFECATING LARVA

The postdefecating larvae of *A. erigeniae* like other *Andrena* (Michener 1953*b*; Michener & Rettenmeyer 1956; Stephen 1966*b*; Thorp & Stage 1968; Thorp 1969; Rozen 1973) are C-shaped with distinct transverse dorsolateral tubercles. Thoracic tubercles are ectangular in lateral view while abdominal tubercles re more rounded (Fig. 17). Rozen (1973) described he postdefecating larva of *A. accepta,* a member of he subgenus *Callandrena.* The larva of *erigeniae* more closely resembles the larva of *accepta* than any other species yet described.

Head (Fig. 18, 19, and 20): as in *A. accepta* (Rozen 1973) except parietal bands not apparent. Mandible (Fig. 21): upper apical margin with three large teeth, lower margin without small denticles.

Body (Fig. 17, 22, and 23): as in *A. accepta* (Rozen 1973) except without setae, dorsum nonspiculate; 10th abdominal venter nonspiculate; anterior surface of ventral tergites densely spiculate; posterior surface of ventral tergites sparsely spiculate; spicules extending laterally to just above the spiracles.

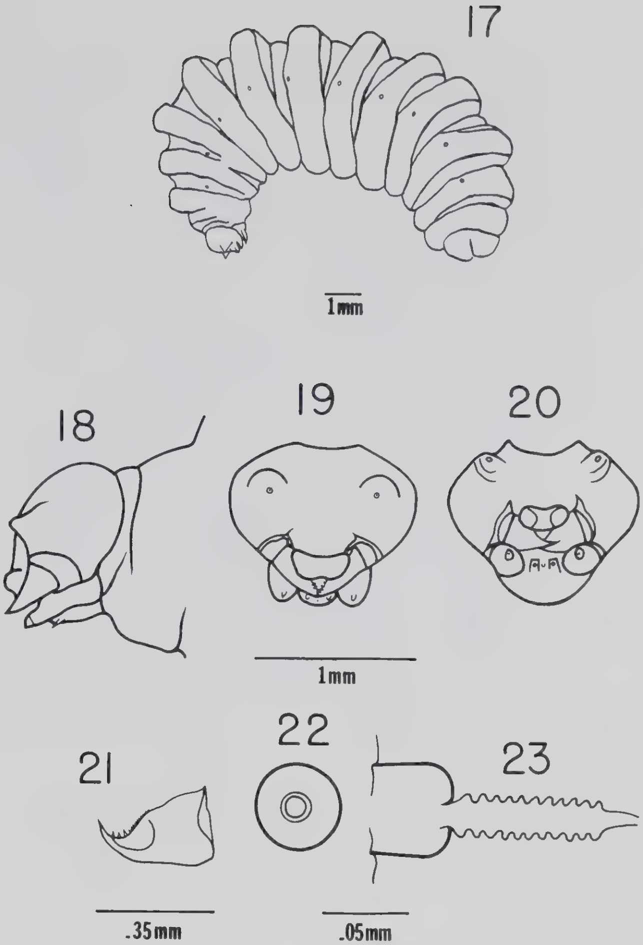

Fig. 17–23.—Drawings of postdefecating larva of *Andrena erigeniae.* 17.—Lateral view of larva. 18.—Lateral view of head capsule. 19.—Frontal view of head capsule. 20.—Ventral view of head capsule. 21.—Ventral view of right mandible. 22.—Surface view of spiracle. 23.—Longitudinal section of spiracle.

INQUILINISM AND PARASITISM

Female bees carrying pollen were observed being shadowed or followed closely by the anthomyiid fly, *Leucophora obtusa* (Zetterstedt). This fly was frequently seen resting on plants or on the ground in the nesting sites. Bees weaving over the area searching for their burrows were often followed at a short distance. A fly would almost exactly follow the rapid meandering flight of the bee. When the bee entered its nest, the fly landed, entered, and then left a few minutes before the bee emerged. Occasionally the bee would land clumsily a short distance from the nest and then turn and face the fly which had landed close behind. A face-off a few centimeters in diameter then took place with the two insects walking in a circle while facing each other. The bee occasionally attacked the fly during such an encounter.

Similar observations have been made by others. Hirashima (1962) observed "a small dipterous fly belonging to the family Muscidae" pursue the female of *Panurginus crawfordi*. Hirashima found the larvae of these flies consuming the pollen in bee cells. Unfortunately these flies were not determined as to species. Michener & Rettenmeyer (1956) observed *A. bipunctata* females being followed by *Leucophora obtusa*. Huie (1916) observed the behavior of a Scottish anthomyiid that chased the females of *A. analis* Panzer.

How the fly larvae get into the bee cells is unknown. According to Stephen, Bohart, & Torchio (1969) anthomyiid flies of the genus *Hammomya* (=*Leucophora*, Huckett 1940) lay their eggs on the host's pollen mass as it is being carried into the nest. However, Michener & Rettenmeyer (1956) noted a different type of behavior for the *L. obtusa* after they observed it following *A. bipunctata*, which leaves its burrow full of loose particles of dirt. After the *bipunctata* female had entered its nest, the fly was observed to land and insert several elongate white eggs into the loose soil of the tumulus (Michener & Rettenmeyer 1956). It is interesting that the larvae of this fly were not found in any of the nests of *bipunctata* which were later excavated (Michener 1974, personal communication). Huie (1916) and Charbonnier (1901) have observed an anthomyiid fly that entered the bee's nest after the bee had left, came out of the hole, and then re-entered backwards to oviposit. This behavior was not observed with *L. obtusa*.

If the anthomyiid eggs are laid on the pollen being carried by the female bee, why are they not destroyed either accidentally or directly by the bee while it is removing the pollen load or shaping it into a ball? Certainly the eggs are much larger than the individual pollen grains. It is difficult to believe that the bee would not recognize such large objects as foreign and either destroy or remove them from the nest. This would seem to be especially true for those fly eggs that happened to be transmitted to the cell on the first load of pollen for that cell.

Excavation of the nests of *A. erigeniae* commonly revealed the presence of various-sized fly larvae in the cells. One cell was found to contain three diptera larvae, of which two were large fourth instar larvae while the third was very small and thought to be a first instar larva. Several other cells contained two large larvae and others contained only one or the larva of *erigeniae* (Fig. 13 and 14). The rate of inquilinism varied. Some nests were almost entirely devoid of bee larvae because of the presence of these flies. Others were not affected. The infestation seemed to be heaviest where the nest density was the highest. The three nests dug on April 25, 1974 at a low density nesting area were free of inquilines.

Some discussion seems justified concerning the observation that three fly larvae of two different sizes were found in one cell. How are larvae of different sizes in the same cell? The first possible answer is that the eggs of the fly were brought into the nest by the bee at two different times. If, for example, the bee brought in the first two fly eggs with a load of pollen and was unable to fly for the next couple of days due to inclement weather, the first two eggs would get a head start on any eggs that happened to be brought in with the next pollen trips. Perhaps a better answer is that the food supply in the cell is only enough to support two fly larvae to adulthood. If this is so, then the third larva might merely have been out-competed for the available food and was stunted from lack of sufficient nourishment. A third possibility is that the fly eggs are deposited in the burrow and, after hatching, the larvae actively seek the cells. If this is the case, the size difference might be accounted for simply by different arrival times of the larvae. Michener & Rettenmeyer's (1956) observation that the fly inserted eggs into the tumulus lends support to this idea.

Note that these flies are referred to as inquilines and not parasites. This is because they do not depend on the body of the bee larva as their source of nourishment (Huie 1916; Askew 1971) and because they may not be directly responsible for the demise of the bee (Hirashima 1962). One excavated cell contained both a first instar bee larva on the pollen ball and a first instar dipterous larva on the wall of the cell (Fig. 24). Some nests contained cells with diptera larvae and a mold on the pollen ball (Fig. 25). Other cells contained diptera larvae and the remains of the pollen ball, which had been reduced to a pale yellow, soupy mass. Hirashima (1962) has suggested that the change in the consistency of the pollen mass may cause the demise of the bee larva. Huie (1916) reported an anthomyiid fly larva that devoured a bee larva that had stopped feeding after its pollen became moldy. The fly larva consumed the fungus-ridden pollen ball first and only attacked the bee larva after all other food was gone.

Although no quantitative records of developmental times were obtained for the Anthomyiid flies, they appeared to undergo a very rapid development as compared to that of the bee larvae feeding on the same materials. After reaching the fourth instar, the diptera larvae burrow out of the cell and pupate in the surrounding soil. Collecting records (Huckett 1940) indicate that this species is univoltine and overwinters in the soil. Pupae of our flies are being kept to compare with adult *L. obtusa* observed around the nesting site.

L. obtusa is not restricted to *A. erigeniae* pollen balls. It was also observed following a small *Simandrena* (probably *nasonii* Robertson) that was nesting in the *erigeniae* nesting site. Michener & Rettenmeyer (1956) found it following *A. bipunctata* in Kansas. Collecting records indicate that it is found as far west as California (Collin 1920; Huckett 1940)

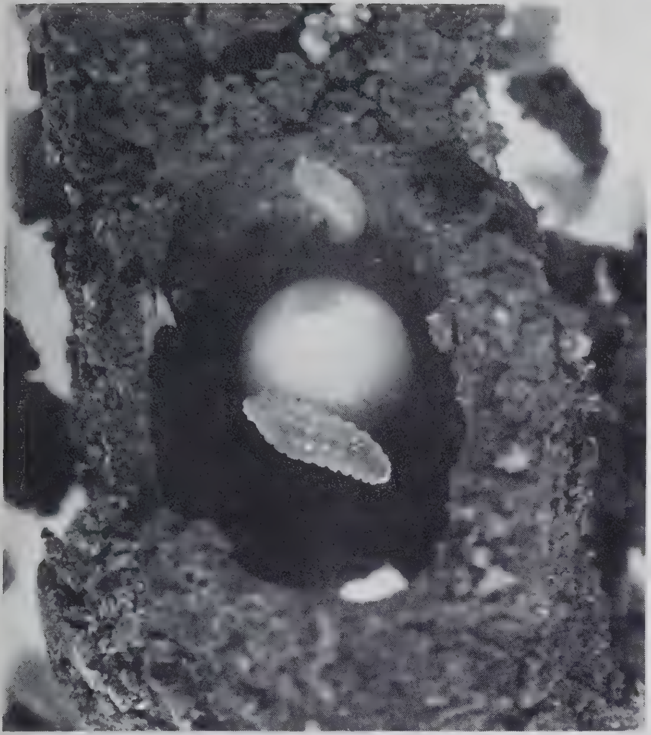

Fig. 24.—Larva of *Andrena erigeniae* on a pollen ball and a small dipterous larva on the wall of the cell.

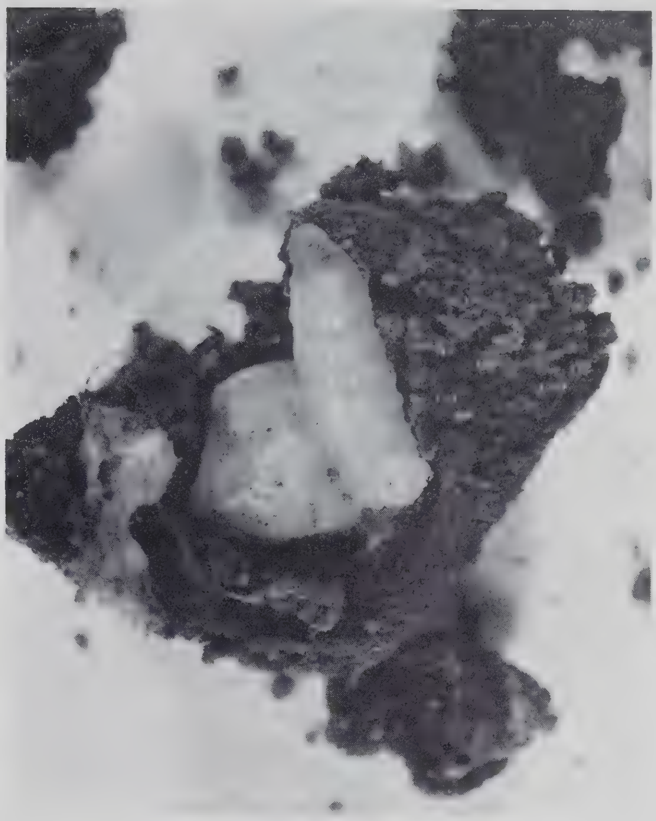

Fig. 25.—Large dipterous larva found in the cell of an *Andrena erigeniae*. Note that no bee larva was present, and the large amount of deteriorating pollen and fungus in the cell.

and its presence has been noted in Great Britain. Therefore, it undoubtedly subsists on the provisions of a number of different species of bees.

During the course of this study two species of *Nomada* (Anthophoridae) were captured flying over the nest site and visiting flowers in the nesting area. However, none were seen entering the nests of *A. erigeniae*.

A. erigeniae is sometimes parasitized by stylopids (Robertson 1891; Robertson 1910; Robertson 1918; Pierce 1909; Pierce 1918; Salt 1927). Of the pinned museum specimens examined during the course of this study only 2 out of 430 were stylopized. The data on these two specimens are: Mahomet, Illinois, April 26, 1925, coll. A.S.B. (Beardsley); Stillwater, Oklahoma, III-24-1936, coll. Myron Maxwell. Both specimens may be designated as female and neither was carrying pollen when collected. Salt (1927) noted that he had examined two females of *erigeniae* that were stylopized. Pierce (1918) described *Stylops erigeniae* from two specimens taken from a female *erigeniae* (unverified identification). This bee was collected at Plummers Island, Maryland, March 29, 1915, by J. C. Crawford. Pierce (1918) also noted a stylopized *A. erigeniae* collected at Carlinville, Illinois, April 1, by Charles Robertson.

A few other insects that might be considered to be accidental intruders were occasionally seen entering the nests of *A. erigeniae*. These include the nitidulid beetle, *Glischrochilus quadrisignatus* Say; the hydrophilid beetle, *Sphaeridium scarabaeoides* L. (both identified by Lloyd Davis), and an undetermined ant (Formicidae). None of these insects remained in the burrows for long and seemed to have entered the burrow by chance. Other accidentals found associated with the cells of *erigeniae* were enchytrid earthworms of undetermined species (identified by L. J. Stannard). These worms were found in two cells from different nests. One of the cells had been penetrated lengthwise by a small root. No bee larvae were found in either cell, although the remains of the pollen ball were still evident.

The role of fungus in destroying bee larvae and provisions is not well understood (Linsley 1958; Stephen, Bohart, & Torchio 1969). Although fungus apparently does destroy cells, it appeared that many of the cells that had fungus had previously been occupied by inquilines (Fig. 25) or disrupted by roots. It would seem likely that a moist environment like the soil in the nest site would make the nests very susceptible to fungus. Do the bees produce some type of fungal inhibitor (suggested by Stephen, Bohart, & Torchio 1969) that is incorporated into the cell or provisions during construction? Perhaps such a substance is manufactured by the bee larva. Further work in this area is needed.

LITERATURE CITED

Alexander, J. D., and J. E. Paschke. 1972. Soil survey: La Salle County, Illinois. Illinois Agricultural Experiment Station Soil Report 91:1–140.

Askew, R. R. 1971. Parasitic insects. American Elsevier Publishing Co., New York. 316 p.

Atwood, C. E. 1933. Studies on the Apoidea of western Nova Scotia with special reference to visitors to apple bloom. Canadian Journal of Research 9:443–457.

Bailey, L. W. 1962. Properties of soils developed near the forest-prairie border in east-central Illinois. M.S. Thesis, University of Illinois. 61 p.

Boggess, W. R., and L. W. Bailey. 1964. Brownfield Woods, Illinois: woody vegetation and changes since 1925. American Midland Naturalist 71:392–401.

Charbonnier, H. J. 1901. Diptera and *Nomada* at *Halictus* burrows. Entomologist's Monthly Magazine 37:48.

Collin, J. E. 1920. A contribution towards the knowledge of the anthomyid genera *Hammomyia* and *Hylephila* of Rondani (Diptera). Royal Entomological Society of London Transactions 69:305–326.

Hirashima, Y. 1962. Systematic and biological studies of the family Andrenidae of Japan (Hymenoptera, Apoidea). Part I. Biology. Faculty of Agriculture, Kyushu University Journal 12:1–20.

Huckett, H. C. 1940. The North American species of the genera *Leucophora* Robineau-Desvoidy and *Proboscimyia* Bigot (Muscidae, Diptera). New York Entomological Society Journal 48:335–365.

Huie, L. H. 1916. The habits and life-history of *Hylemyia grisea* Fall., an anthomyiid fly new to the Scottish fauna. Scottish Naturalist 49:13–20.

Knerer, G., and C. E. Atwood. 1964. An annotated check list of the genus *Andrena* in Ontario (Hymenoptera: Andrenidae). Entomological Society of Ontario Proceedings 94:41–56.

LaBerge, W. E. 1964. Prodromus of American bees of the genus *Andrena* (Hymenoptera, Apoidea). University of Nebraska State Museum Bulletin 4:279–316.

————. 1967. A revision of the bees of the genus *Andrena* of the Western Hemisphere. Part I. *Callandrena*. (Hymenoptera: Andrenidae). University of Nebraska State Museum Bulletin 7:1–316.

Linsley, E. G. 1958. The ecology of solitary bees. Hilgardia 27:543–599.

————, and J. W. MacSwain. 1959. Ethology of some *Ranunculus* insects with emphasis on competition for pollen. University of California Publications in Entomology 16:1–45.

————, ————, and R. F. Smith. 1952*a*. The bionomics of *Diadasia consociata* Timberlake and some biological relationships of emphorine and anthophorine bees (Hymenoptera; Anthophoridae). University of California Publications in Entomology 9:267–290.

————, ————, and ————. 1952*b*. Outline for ecological life histories of solitary and semi-social bees. Ecology 33:558–567.

————, ————, and ————. 1955. Observations on the nesting habits and flower relationships of some species of *Melandrena* (Hymenoptera: Andrenidae). Pan-Pacific Entomologist 31:173–185.

MacSwain, J. W. 1945. Nesting habits of *Andrena rhodotricha* Linsley (Hymenoptera-Andrenidae). Pan-Pacific Entomologist 21:134.

Malyshev, S. I. 1936. The nesting habits of solitary bees, a comparative study. EOS–Revista Española de Entomología 11:201–309.

Michener, C. D. 1953*a*. Life-history studies in insect systematics. Systematic Zoology 2:112–118.

————. 1953*b*. Comparative morphological and systematic studies of bee larvae with a key to the families of Hymenopterous larvae. University of Kansas Science Bulletin 35:987–1102.

————, E. A. Cross, H. V. Daly, C. W. Rettenmeyer, and A. Wille. 1955. Additional techniques for studying the behavior of wild bees. Insectes Sociaux 2:237–246.

————, and C. W. Rettenmeyer. 1956. The ethology of *Andrena erythronii* with comparative data on other species (Hymenoptera, Andrenidae). University of Kansas Science Bulletin 37:645–684.

Mitchell, T. B. 1960. Bees of the eastern United States. North Carolina Agricultural Experiment Station Technical Bulletin 141, 1:1–538.

Osgood, E. A. Jr. 1972. Soil characteristics of nesting sites of solitary bees associated with the low-bush blueberry in Maine. Maine Life Sciences and Agriculture Experiment Station Technical Bulletin 59. 8 p.

Page, J. L. 1949. Climate of Illinois. Agricultural Experiment Station Bulletin 532:95–364.

Perkins, R. C. L. 1919. The British species of *Andrena* and *Nomada*. Royal Entomological Society of London Transactions 67:218–319.

Pierce, W. D. 1909. A monographic revision of the twisted winged insects comprising the order Strepsiptera Kirby. U.S. National Museum Bulletin 66:1–232.

————. 1918. The comparative morphology of the order Strepsiptera together with records and descriptions of insects. U.S. National Museum Proceedings 54:391–501.

Rau, P. 1935. Notes on the nesting habits of the red-bellied bee, *Andrena erythrogaster* Ash. (Hymen.: Andrenidae). Entomological News 45:35–37.

Robertson, C. 1891. Descriptions of new species of North American bees. American Entomological Society Transactions 18:49–66.

————. 1910. Hosts of Strepsiptera. Canadian Entomologist 42:323–330.

————. 1918. Bees and Strepsiptera. Brooklyn Entomological Society Bulletin 13:83–85.

————. 1929. Phenology of oligolectic bees and favorite flowers. Psyche 36:112–118.

————. 1930. Proterandry and flight of bees. III. (Hym.: Apoidea). Entomological News 41:331–336.

Rozen, J. G. Jr. 1968. Biology and immature stages of the aberrant bee genus *Meliturgula* (Hymenoptera, Andrenidae). American Museum Novitates 2331:1–18.

————. 1973. Biology notes on the bee *Andrena accepta* Viereck (Hymenoptera, Andrenidae). New York Entomological Society Journal 81:54–61.

Salt, G. 1927. The effects of stylopization on aculeate Hymenoptera. Journal of Experimental Zoology 48: 223–331.

Sivik, F. P. 1954. Ecological notes on three species of solitary bees. Entomological News 65:253–256.

Stephen, W. P. 1966*a*. *Andrena* (*Cryptandrena*) *viburnella*. I. Bionomics. Kansas Entomological Society Journal 39:42–51.

————. 1966*b*. *Andrena* (*Cryptandrena*) *viburnella*. II. External morphology of the larva and pupa. Kansas Entomological Society Journal 39:51–53.

————, G. E. Bohart, and P. F. Torchio. 1969. The biology and external morphology of bees, with a synopsis of the genera of northwestern America. Oregon Agricultural Experiment Station Bulletin. 140 p.

Thorp, R. W. 1969. Systematics and ecology of the bees of the subgenus *Diandrena* (Hymenoptera: Andrenidae). University of California Publications in Entomology 52:1–146.

————, and G. I. Stage. 1968. Ecology of *Andrena placida* with descriptions of the larva and pupa. Entomological Society of America Annals 61:1580–1586.

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DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION

APPARATUS AND PROCEDURE FOR EXTRACTING CORN ROOTWORM EGGS FROM SOIL

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ROBERT O. ELLIS
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The northern and western corn rootworms complete one life cycle each year. They oviposit eggs in soil in August and September. The eggs develop slightly, go into a resting stage during the winter, and hatch in the following spring. The potential for damage by the larvae of these insects in the next growing season can be determined by counting the number of eggs per unit of soil. However, it is physically impossible to count these eggs without some means of extracting them from the soil, since rootworm eggs are slightly smaller than the period at the end of this sentence.

Researchers at the University of Missouri (Chandler et al. 1966) developed a machine for separating rootworm eggs from soil. A sample of soil containing eggs is saturated with sodium hypochlorite and water, and the sample is agitated for 15-20 minutes on a ball mill. The sample is then passed in small amounts through a slowly revolving screen cylinder and washed with sprays of water from fixed nozzles and a hand sprayer. The eggs are collected in a fine-mesh screen trap for final processing.

Using the basic design of the Missouri separator, we engineered a larger, enclosed machine that extracts rootworm eggs from a pint of soil in 3-4 minutes. The final stages of separating eggs from debris require another 5 minutes after which the eggs can be counted under a microscope. The Illinois machine and the final separation of eggs, using magnesium sulphate, are highly efficient, and we have repeatedly recovered 97 percent of rootworm eggs manually placed in samples of soil. Weed scientists in the Department of Agronomy, University of Illinois, also have used the machine to extract weed seeds from soil samples in their weed pest-management program.

The Illinois machine is constructed of stainless steel, and all seams are welded watertight. The table top and cabinetry are made of stainless steel sheeting, and the supporting framework is 1/8-inch stainless steel angle frame. The plumbing is connected directly to a domestic water source. An external view of the machine, with dimensions, is shown in Fig. 1.

A soil sample is placed in the sieve insert in the 9-inch diameter funnel beneath the shower head, and the sample is sprayed with full water pressure. The funnel-shaped sieve insert constructed of 30-mesh T-304 stainless steel screen fits inside the funnel with 1-inch clearance between the mesh sieve and the funnel. The wire for the sieve insert has a diameter of 0.01 inch, a mesh opening of 0.023 inch, and a weight of 20 pounds per 100 square feet. Fifty percent of the sieve's surface is open area, allowing an easy, rapid flow of eggs and soil in suspension. The funnel with the sieve in place is shown in Fig. 2. The shower head is controlled by a foot pedal. The plastic garbage can under the machine collects waste water and soil. Residues of soil that cling to the sides of the sieve, the receiving funnel, and the funnel immediately below are flushed down with water sprayed from a common kitchen sink sprayer.

The internal design is illustrated in Fig. 3. A 1/10-horsepower 60-RPM gearmotor, using drive-pulley reduction to 50 RPM, slowly rotates a 50-mesh T-304 stainless steel screen cylinder. The wire for the screen cylinder has a diameter of 0.009 inch and a mesh opening of 0.011 inch,

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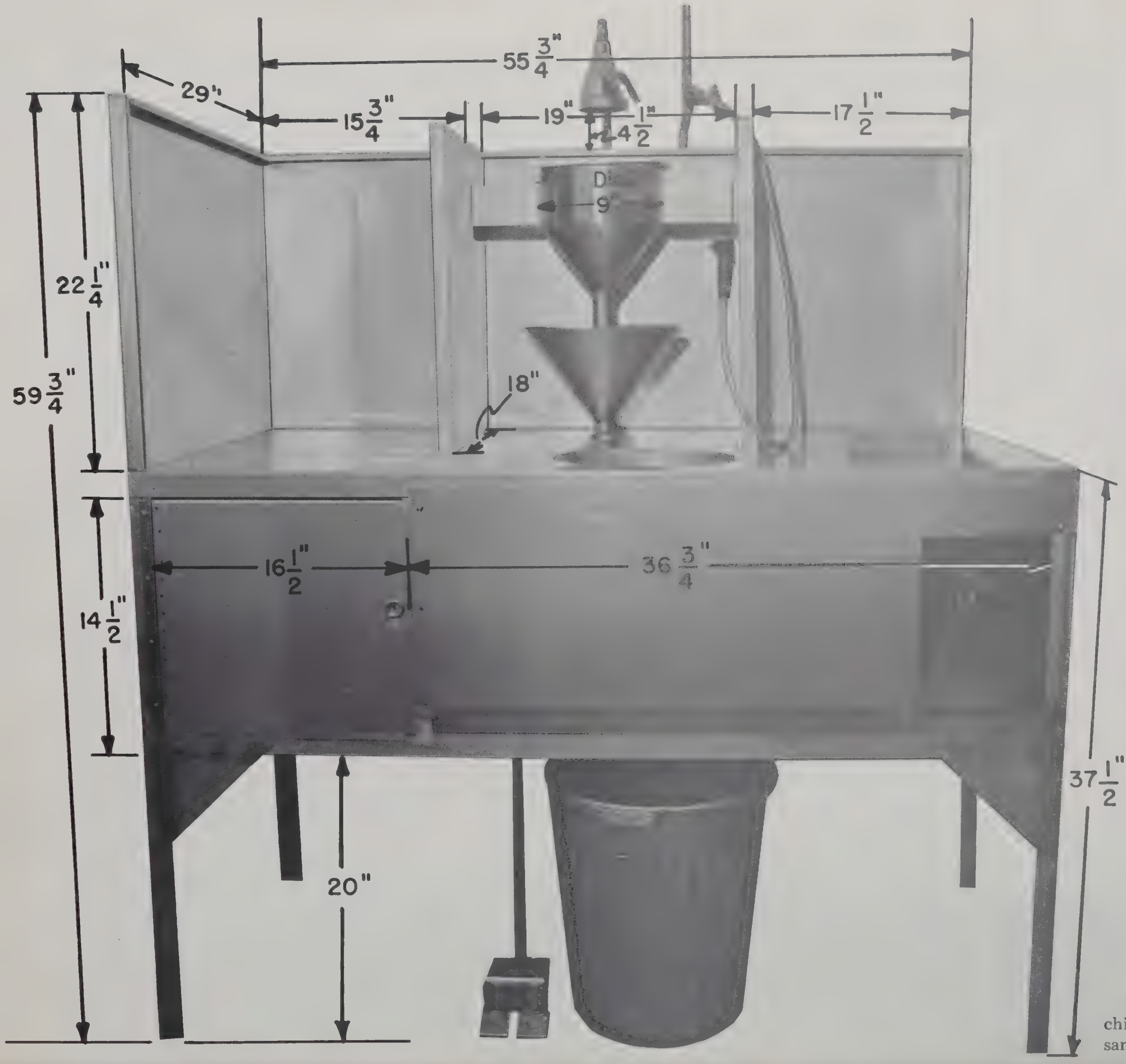

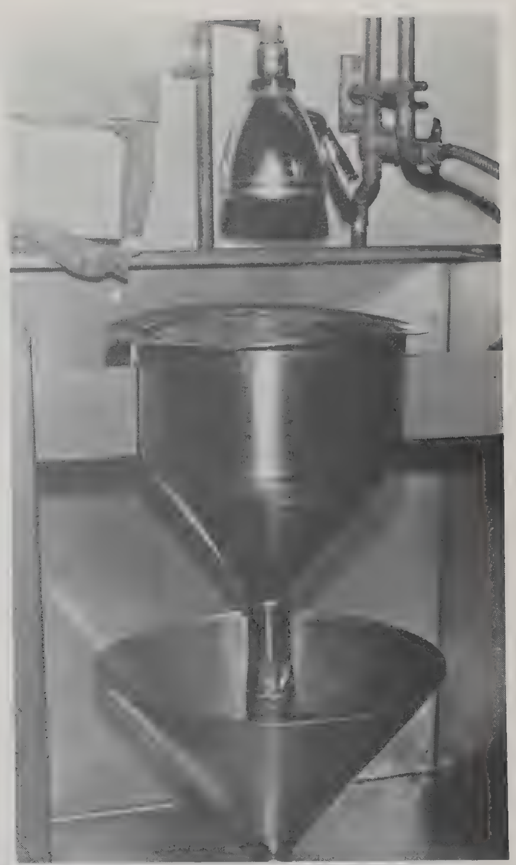

Fig. 2.—Nine-inch diameter funnel with stainless steel sieve insert. A soil sample is placed in the sieve and sprayed with water from the shower head.

Fig. 1.—External view, with dimensions, of machine used to extract corn rootworm eggs from a sample of soil.

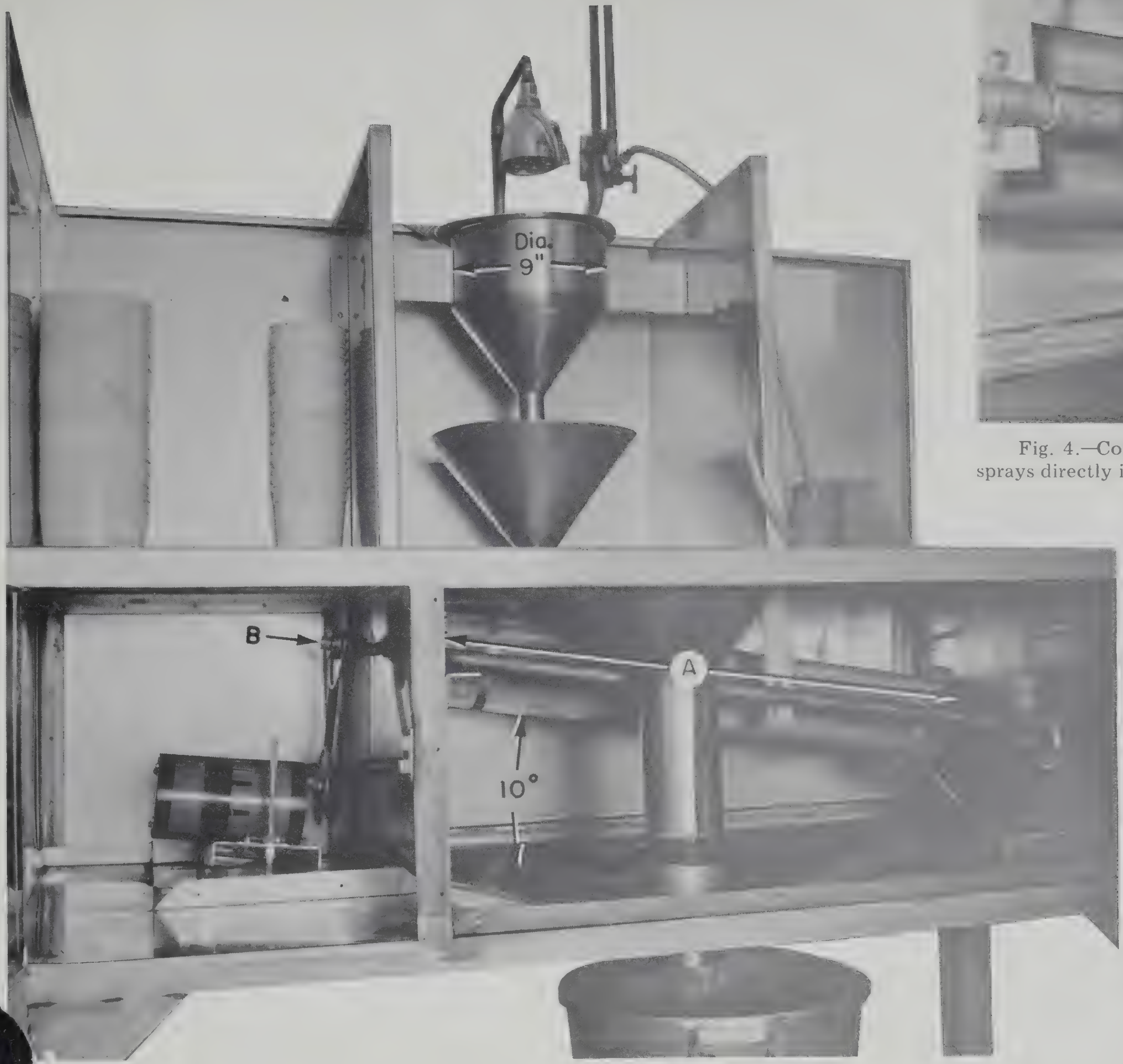

Fig. 3.—Internal design of rootworm egg extracting machine. Stainless steel screen cylinder (A) is 5 inches in diameter and 30 inches long. The screen cylinder and its shaft (B) are sloped 10 degrees.

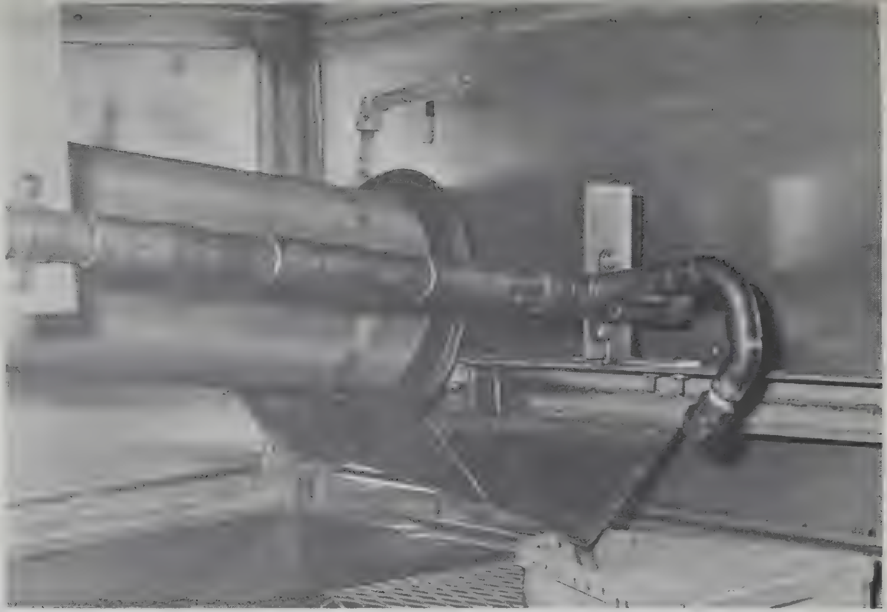

Fig. 4.—Collecting trough and stainless steel screen collecting tray. A nozzle sprays directly into the collecting tray.

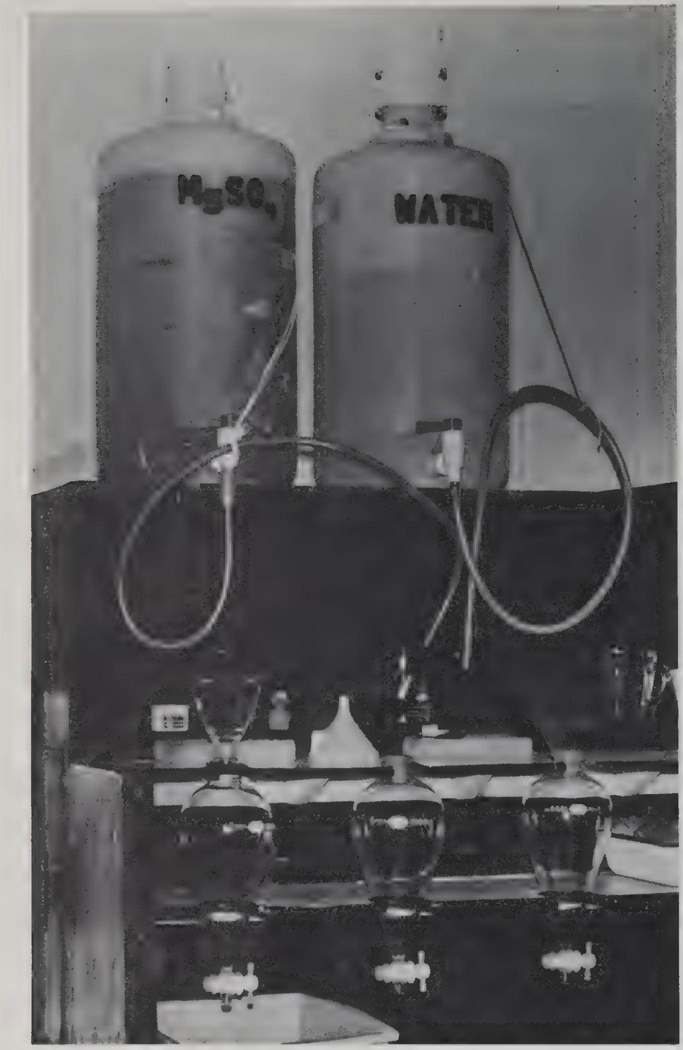

Fig. 5.—Laboratory arrangement for the final separation of corn rootworm eggs from soil. Magnesium sulphate and water flow by gravity into the separatory funnels. The funnels can be removed from the stand.

and 30.3 percent of the screen surface is open area. The wire weight is 28.4 pounds per 100 square feet. The cylinder is 5 inches in diameter and 30 inches long and has a 10-percent slope (the slope is very important). The cylinder is mounted on a 3/4-inch diameter shaft. Seven fan T-jet No. 8004 nozzles mounted both in front of and behind the cylinder spray it with water. If the water pressure is below 35 lb/in^2 at the installation site, special nozzles will be required to compensate for the low pressure. The water containing eggs and soil spills into a trough at the lower end of the cylinder. This trough is slanted toward the front of the machine, causing eggs and soil to drop into a collecting tray constructed of the 50-mesh stainless steel screen used in the cylinder. A nozzle sprays the eggs and debris in the collecting tray. A close-up view of the collecting trough and tray is shown in Fig. 4.

Cleaning the upper surface of the machine is facilitated by a large hole which funnels into the lower unit, and all water and soil is voided through one outlet into the waste container. A stainless steel partition separates the electric-motor compartment from that of the screen cylinder, and for safety a steel mesh guard is located in front of the electric motor.

The screen cylinder is the most important unit in this machine. It is geared to turn at 50 RPM. During construction, the seams of the machine must be carefully soldered so that all surfaces are smooth. This is extremely important. The machine will not be reliable if cracks or uneven areas occur in the cylinder. Extra soldering is necessary to fill minute cracks. Careful soldering is also needed for the collecting tray so that all corners are filled with solder and all surfaces are smooth.

Before using the machine, one collects soil in the field, using an acceptable sampling procedure. A sample may be a composite of subsamples or a number of individual samples taken at various locations in a field. The sample is sifted through a 1/4-inch hardware cloth screen and mixed thoroughly. One pint of soil is measured and placed in the sieve in the top funnel under the shower head. The sample is sprayed for 3 minutes, and any remaining soil is flushed down with the hand-operated kitchen sprayer. The sample moves through the screen cylinder, and in 3-4 minutes all of the eggs and remaining debris collect in the collecting tray. The collecting tray is then sprayed thoroughly with the hand-operated sprayer.

The collecting tray is removed from the machine, and the eggs and remaining debris are flushed into a 1,000-ml separatory funnel with a stopcock opening of approximately 7mm. See Fig. 5 for the arrangement of equipment for the final processing of corn rootworm eggs. Approximately 500 ml (about 1 pint) of 2 mol magnesium sulphate solution ($MgSO_4$) are used to flush the eggs and debris into the funnel. The funnel is shaken vigorously and returned to the holding rack; in about 30 seconds the heavier debris sinks to the bottom of the funnel. The stopcock is then opened, and the debris and about 450 ml of the magnesium sulphate solution are drained from the funnel. Care should be taken not to drain off all of the magnesium sulphate solution, since the eggs will be floating on its surface. The stopcock is closed, 500 ml of water are added to the funnel, and the funnel is shaken again. The sample must settle for no less than 1 minute (this time is critical) to permit the eggs to sink to the bottom of the funnel. Next the stopcock is opened and closed quickly to drain the eggs and about 50 ml of water into a petri dish. The eggs are counted under a binocular microscope, and the number of eggs per pint of soil is recorded. The $MgSO_4$ solution can be reused by straining it through a sieve to remove minor debris.

REFERENCE

CHANDLER, J. H., G. J. MUSICK, and M. L. FAIRCHILD. 1966. Apparatus and procedure for separation of corn rootworm eggs from soil. Journal of Economic Entomology 59:1409-1410.

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ENVIRONMENTAL EVALUATIONS USING BIRDS AND THEIR HABITATS

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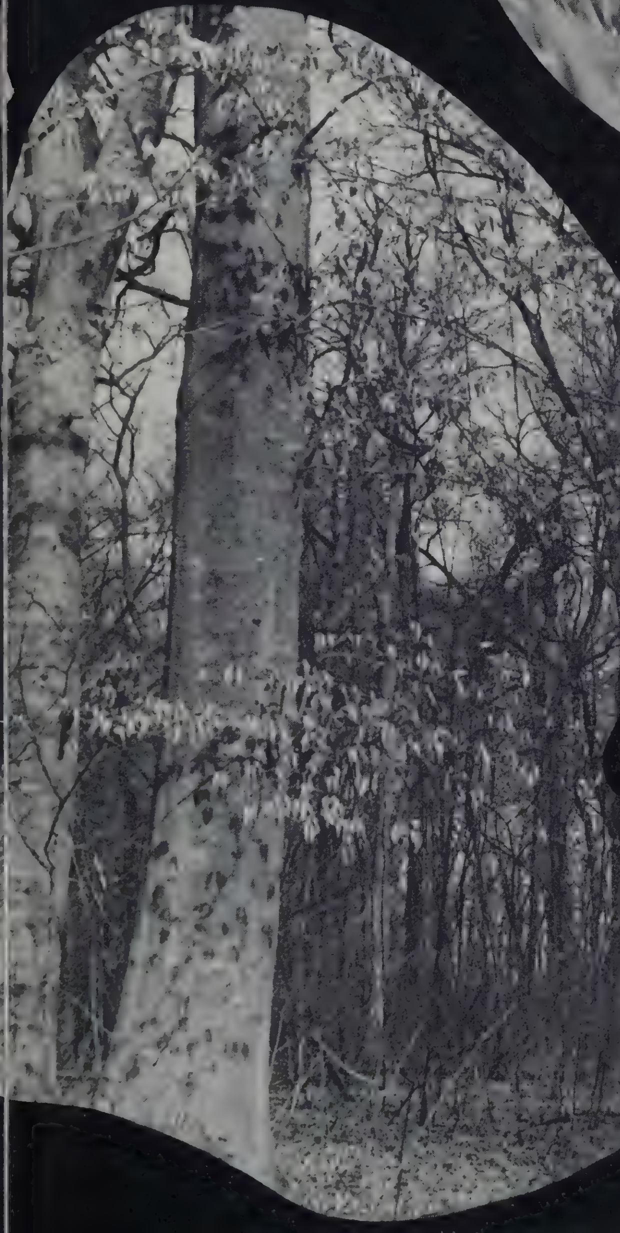

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Environmental Evaluations Using Birds and Their Habitats

Jean W. Graber and Richard R. Grabe

Since the passage of the U. S. National Environmental Policy Act of 1969, the number of requests for bird population data to be used in environmental-impact studies has increased annually at the Illinois Natural History Survey. The problem of evaluating the natural environment is both extremely important and extremely complicated, and no one investigator can know enough to make such an evaluation with complete accuracy. Such evaluations often concern large acreages of land, and the biological investigator is, thus, confronted with an array of habitats that may support thousands of species of organisms, most of them specifically unknown to the investigator and poorly known even to science except by name. Though the Environmental Policy Act did not place strict time limitations on the preparation of impact statements, in practice the investigator is often asked for a report within a time schedule that is wholly unrealistic in view of the magnitude of the task.

Hopkins et al. (1973) discussed environmental-impact statements and their potential contents in a general way, but did not deal with the biological aspects of the problem. A practical standard upon which to base evaluations of biological communities has been lacking. Although land can be considered in terms of the economic value of its various uses, natural communities are beyond the realm of human economics, as there is no place where they can be fabricated or purchased. For this reason ecological values must take precedence over economic ones in the evaluation of natural communities.

Even to attempt to standardize something so complex as an evaluation of natural populations will strike many biologists as ludicrous. Yet there are strong arguments for making the attempt. Presently, all too often, neither the writer nor the reviewer of an environmental-impact statement is fully qualified to make a judgment on the value of a given report or the true impact of a given action upon the environment. With a standard scale upon which impacts can be measured quantitatively, judgments can become more objective regardless of who makes them. The problem of standardizing environmental evaluations seems particularly difficult when it is remembered that the method must be practicable for a large number of different investigators with varied backgrounds. It must, therefore, be simplified as much as possible. From such considerations we developed our method
on what we believe to be logical grounds. The meth
can apply not only to impact studies that invol
the potential destruction or gross alteration of te
restrial habitats, but also to the acquisition of la
for nature preserves.

For practical reasons we have restricted our co
sideration to Illinois, and although the same principl
can be applied to other geographic areas, we ha
provided basic evaluation data only for Illinois. W
did so because Illinois is the area we know best a
because certain types of background data — for e
ample, habitat inventories and census data — ha
traditionally been organized and presented accordi
to state boundaries.

We have based our method of environment
evaluation on bird populations and their gross hal-
tats. Ideally, all elements of the environment -
floral, faunal, geologic, and others — should be co-
sidered in calculating environmental value. In pra-
tice, however, more components of the environme
are ignored than are considered in impact studie
with the vast invertebrate populations being partic-
larly slighted. The omissions are understandable. Fe
investigators are competent to identify all the pla
species they encounter in their field work, let alo
animals and many other constituents of the enviro-
ment. The use of bird data in our method of eval-
ation is not intended to diminish the consideratio
of other environmental components. The greater t
number of groups considered, the more valuable w
be the final statement and judgment. As a practic
matter, however, especially in view of the limitatio
of time and the capabilities of any one investigat
it is reasonable to base the standard on one faun
group and its gross habitats. The fauna and associat
habitats in this case serve as an index to general bi-
logical richness. As will be explained, other faun
or floral groups can be used as we have used bi
populations.

There are arguments both for and against the u
of bird data in this capacity. Bird populations ha
several characteristics that make them useful in
consideration of environmental quality. Birds a
relatively conspicuous and easy to detect. They a
virtually omnipresent — occurring in nearly all te-
restrial and aquatic habitats throughout the wor
excepting water below 200 feet or even (exce
briefly) at shallower depths. Their populations a
measurable and better known than are those of mo
other groups. In Illinois the number of breeding sp-
cies occurring regularly each year (about 180) is n

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ı overwhelming number with which to work. Birds :cupy all gross habitats, and their variety in a given abitat reflects the complexity of the habitat. Birds ake contact with nearly all facets of the environment a number of ways, including the intake of a great ariety of food.

Perhaps the worst characteristic of birds for their se as environmental indicators on a specified area their great mobility, which enables them to migrate hundreds and even thousands of miles and ıanges populations overnight at a given place both uantitatively and qualitatively (Fig. 1 and Table 1). Iost Illinois bird populations are migratory. Few are holly nonmigratory, and even most of the species ıat are seen year round in the state have migratory opulations. Thus, any student of bird populations is onfronted with the problem of migration and how is affecting the populations he is studying.

All bird populations are more or less dependent pon the habitats they occupy, regardless of season, ut the populations that are most stable and most uniormly distributed from day to day and area to area re the breeding populations. Because of this staility and the importance of the nesting habitat to ıe survival of the population, we have, in our conideration of environmental value, used only the nestıg species as faunal indicators.

In identifying and characterizing habitats we have sed Illinois references if available. Otherwise, we have used references on areas as close to Illinois as we could find. This paper is not intended as an inventory of plant communities such as that for southern Illinois by Voigt & Mohlenbrock (1964).

TABLE 1. — Overnight variation in numbers of warblers seen on an area in central Illinois near the Illinois River, May 5 and 6, 1969.

Species	Warblers Seen	
	May 5	May 6
Black-and-white warbler	1	0
Prothonotary warbler	9	3
Tennessee warbler	26	44
Nashville warbler	20	19
Yellow warbler	14	19
Magnolia warbler	0	12
Myrtle warbler	2	5
Black-throated green warbler	1	8
Cerulean warbler	0	1
Blackburnian warbler	0	3
Chestnut-sided warbler	1	2
Bay-breasted warbler	0	1
Blackpoll warbler	1	8
Palm warbler	0	12
Ovenbird	3	5
Northern waterthrush	11	11
Kentucky warbler	3	1
Common yellowthroat	29	20
Yellow-breasted chat	4	1
Canada warbler	1	0
American redstart	39	24
Total birds	*165*	*199*
Number of species	16	19

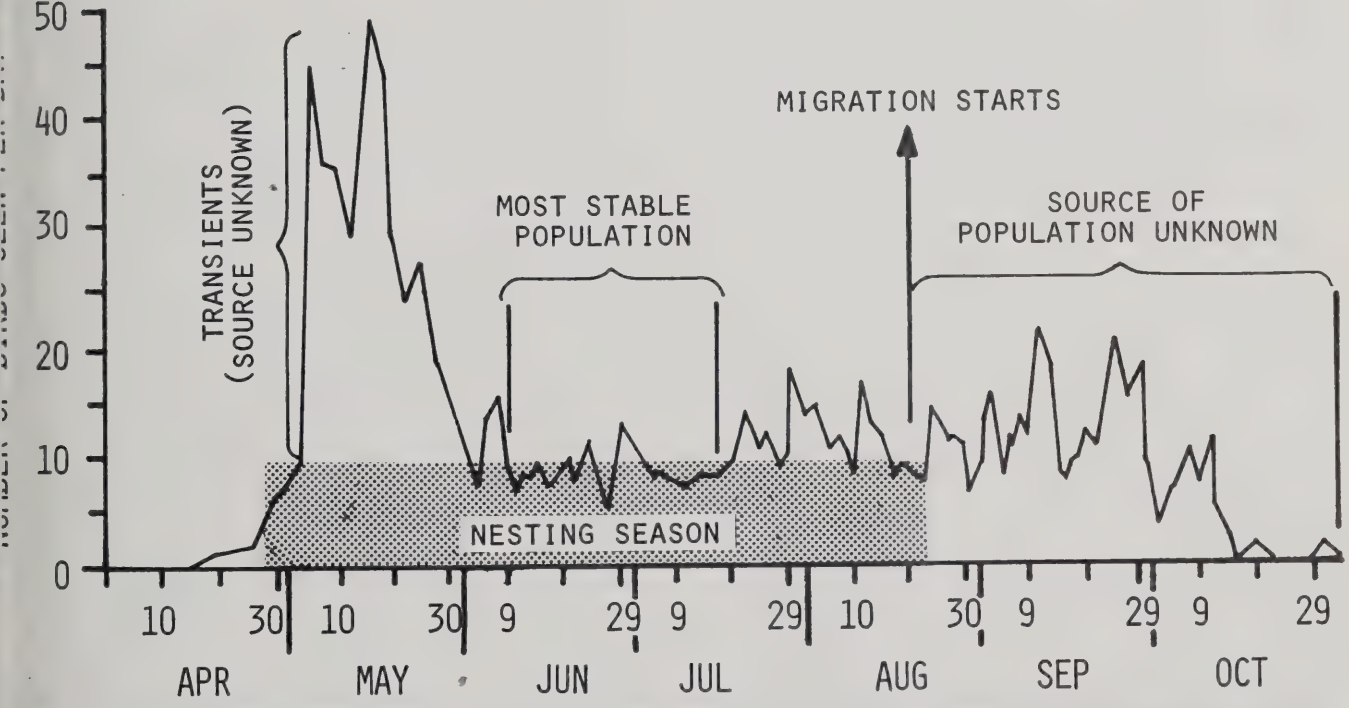

Fig. 1. — Fluctuations in daily counts of a typical migrant species (gray catbird, *Dumetella carolinensis*) that breeds n Illinois. Counts are highest during May when large numbers of migrants and breeding birds are present. Counts are levated in late summer because of reproduction and possibly some migration; however, by this time some breeding birds ıay have left. In the fall there is fluctuation and constant turnover during migration.

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Plant nomenclature in this paper follows Jones (1963), and the nomenclature for birds follows the American Ornithologists' Union *Check-list of North American Birds* (1957) and its supplements. We have created names for the various factors used in calculating environmental quality, and these are capitalized in the text and tables.

We are particularly indebted to Glen C. Sanderson, Head of the Survey's Section of Wildlife Research, for his comments and extensive editing of the first complete draft of the manuscript and to our other Survey colleagues, Robert A. Evers (Botany and Plant Pathology Section), Charles M. Nixon (Wildlife Research), and Lewis J. Stannard (Faunistic Surveys and Insect Identification Section) for their suggestions and comments on the manuscript. Robert M. Zewadski, Survey Technical Editor, edited the final draft of the paper.

DERIVATION OF THE EVALUATION METHOD

Regardless of which or how many faunal or flora groups are considered in evaluating an area, investigators are always dealing with habitats of variou types, and the fundamental value of the natural environment is the value of the habitat, usually define by its vegetation. In essence, our method of evaluation is based upon: (1) the "cost" of each habitat specifically its replacement cost as measured in time (2) the availability of each habitat, as indicated b its total area in the state or a region of the state (3) the changing availability (if changing) of eac habitat; (4) the amount of each habitat in the impact area; and (5) the faunal and/or floral complexity of each habitat.

We use these factors in calculating indices t environmental value by converting the factors t numerical values that reflect natural parameters o

TABLE 2. — Estimated replacement times for gross habitats in Illinois.

Gross Habitats	Years of Successional Lead-in Time	Years of Replacement Time	References
Bottomland forest			
Oak-gum-cypress	100–150	20–600	Anderson & White (1970), Shelford (1954)
Elm-ash-cottonwood by age			
5–29 years (willow-cottonwood)	35	5–29	Shelford (1954)
30–59 years (willow-cottonwood-maple)	35	30–59	"
60–99 years (hackberry-gum)	35	60–99	"
100+ (hackberry-gum, elm-oak-hickory, and succession to climax)	135–600	100–500[a]	"
Upland forest by age			
10–29 years (black cherry-elm-hawthorn, elm-persimmon-sassafras)	25	10–29	Bazzaz (1968), Beckwith (1954)
30–59 years (elm-oak-hickory)	50	30–59	
60–99 years (oak-hickory)	100	60–99	Odum (1953)
100+ (oak-hickory with possible succession to maple-beech)	100+	100–500[a]	
Maple-beech	150–200+	35–500+[a]	
Aspen	5	5–39	Essex & Gansner (1965)
Pine forest by age			
10–39 years	25	10–39	Odum (1953)
40+	25	40–100+	
Shrub areas	3	3–30	Bazzaz (1968), Beckwith (1954)
Residential habitat	...	1–100+	This paper
Marsh, natural	1,000+	600+	"
Marsh, man-made	3	3–100+	"
Prairie	10–15	10–30+	Booth (1941), Thomson (1940), Weaver (1961)
Ungrazed and fallow fields	...	1–10	This paper
Pastures	...	1–10	"
Hayfields	...	1–3	"
Small-grain fields	...	1	"
Row-crop fields	...	1	"

[a] Time based on sizes of largest trees in Illinois (Mohlenbrock 1973) and growth rates for these species.

habitats. We then use the number values in simple equations to determine two indices of environmental value — the Habitat Evaluation Index and the Faunal (or Floral) Index. We will first define the five factors and then the gross habitats to which they apply. Finally, we will explain how our method of evaluation is used and provide examples.

Replacement Cost of the Habitat

Replacement cost is defined as the time required to re-establish a particular biocommunity. Although natural communities cannot be purchased, they can perhaps be developed, given enough time. Even such development, however, is problematical, as every natural community is unique. The possibility of reproducing, after its destruction, precisely the same natural community in terms of mineral, floral, and faunal composition seems remote even given large amounts of time. On the other hand, the community itself is not static, but changes day to day, season to season, and year to year. Once a natural community has been destroyed, about the best that can be hoped for by way of replacement is that the forces which formed it in the first place, with or without human intrusion, will, in time, bring something similar into being. Such replacement, however, is contingent upon an absolute and irrefutable requirement — that the living components of the community have not been removed to extinction.

There is a relationship between the age of a given habitat and its value that concerns the time cost of developing the habitat once it is destroyed. Thus, a plowed field has essentially zero replacement time compared to a centuries-old forest. For the practical purposes of our evaluation, we can use as the replacement cost a numerical factor equal to the age of the habitat in years plus, in some cases, a successional lead-in period. We call this the Replacement Factor, and its range of values for the gross habitats in Illinois are given in Table 2. The replacement times given in that table refer to situations in which the soil is left in place. On impact areas where the soil is removed or substantially altered, a successional lead-in time must be added to the regrowing period. A further explanation of the Replacement Factor and its use is presented in the discussion of each habitat type and in the section on The Method in Practice.

Habitat Availability

Habitat availability refers simply to the amount — the acreage — of a particular gross habitat in a specified geographical area. After the replacement cost of the habitat, we consider the next most important factor to be the availability of the habitat. We at first considered the matter of availability of habitats on a county-by-county basis, but the available acreage data were not sufficiently refined for this method. We were also concerned about the possibility that impact areas would often cross county lines, thus complicating calculations of environmental value. We finally compromised by considering the state in terms of three regional divisions (Fig. 2). The regions, as drawn, are artificial, but have some general biological significance. For example, cypress forest occurs naturally only in the southern region, and white pine only in the northern region. The factor for availability, then, is based on the estimated acreages of each gross habitat in each region of the state (Table 3).

In seeking acreages for the different habitats, we

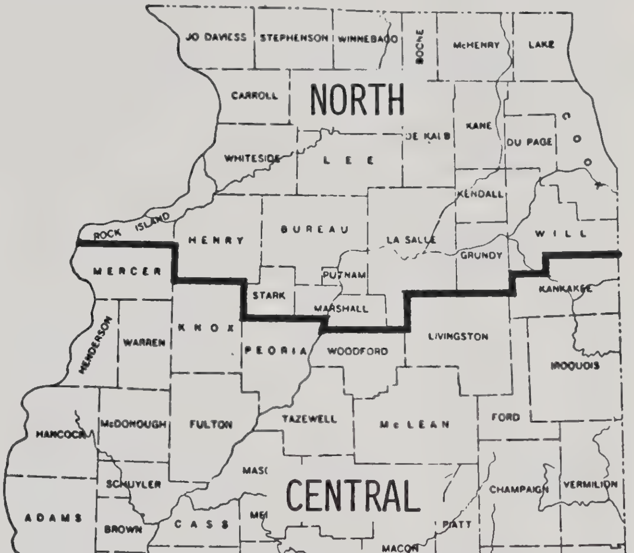

Fig. 2. — The limits of the three Illinois regions (north, central, and south) referred to in this paper.

TABLE 3. — Acreage estimates of gross habitats in three regions of Illinois as of 1973. Because of the rounding of figures to the nearest 100 acres, columns may show discrepancies in subtotals and totals.

Gross Habitats	North	Central	South	State
Land and water	8,694,100	16,050,900	10,374,400	35,119,40
Inland impoundments	60,000	94,100	119,800	273,80
Rivers and streams	106,400	161,000	113,700	381,10
Land area	8,527,700	15,795,800	10,140,900	34,464,40
Bottomland forest				
Oak-gum-cypress by age				
to 99 years	...	...	4,200	4,20
100+	...	...	8,400	8,40
Subtotal	...	...	12,600	12,60
Elm-ash-cottonwood by age				
to 29 years	20,900	75,200	170,500	266,60
30–59	31,400	112,900	256,000	400,30
60–99	11,300	40,500	92,000	143,80
100+	1,300	4,400	9,800	15,50
Subtotal	64,900	233,000	528,300	826,10
Upland oak-hickory by age				
to 29 years	39,100	145,100	309,800	494,00
30–59	66,500	246,700	526,800	840,00
60–99	44,400	164,800	351,900	561,10
100+	10,500	38,800	82,900	132,20
Subtotal	160,500	595,400	1,271,500	2,027,40
Maple-beech by age				
to 49 years	1,100	3,100	3,700	7,90
50+	1,000	2,700	3,100	6,80
Subtotal	2,100	5,800	6,800	14,70
Aspen	6,400	3,000	...	9,40
Pine forest by age				
to 39 years	2,600	8,400	36,400	47,40
40+	800	2,600	11,400	14,80
Subtotal	3,400	11,000	47,800	62,20
Shrub areas	35,600	100,000	184,200	319,90
Residential habitat	958,300	543,000	303,600	1,804,90
Marshes	31,700	16,700	3,400	51,80
Prairie	5,300	1,700	1,400	8,50
Ungrazed and fallow fields	596,600	702,100	436,500	1,735,20
Pastures	750,200	1,563,400	1,115,900	3,429,50
Hayfields	451,600	452,800	389,100	1,293,50
Small-grain fields	371,800	650,500	980,700	2,003,00
Row-crop fields	4,764,000	10,618,500	4,141,500	19,524,00
Habitat acreage	8,202,600	15,496,800	9,423,300	33,122,60
Nonhabitat acreage (hard surfaces of roads, railroads, and airstrips)	112,100	177,800	113,800	403,70
Land accounted	8,314,600	15,674,600	9,537,100	33,526,40
Land unaccounted	213,100	121,200	603,800	938,10

found that no two authorities give even the same land acreage for Illinois though all indicate a figure of around 36 million acres. Lopinot's (1973) inventory of surface water areas is the most recent and comprehensive report on water, versus land, areas in the state, and we used his figures on land and water areas of the counties as a starting place. There is no complete detailed inventory of natural habitats in Illinois, or any sizeable part of the state, and such an inventory is very much needed. Our estimates for the acreages of natural habitats are rough at best, but they are based wherever possible on published census figures. The published sources we used have their own built-in errors, as the authors usually explain, and the user of our work should refer to the original references for information on ranges of error and data reliability. Our estimates probably compound the errors of the original sources, because we have attempted to bring the acreage estimates up to the year 1973. This is the most recent year for which crop acreage figures were available, and crop acreages are probably the most comprehensive estimates, since agricultural land accounts for most of the land in the state. Acreages of all habitats are changing rapidly now, and so we attempted to bring the acreage estimates up to date as much as possible.

Our sources and methods of estimating the 1973 acreages are presented in the discussion of each type of habitat.

Though we made extensive searches of the Illinois literature in an effort to account for all the land acreage, when the task was completed we could not account for 938,000 acres of Illinois (Table 3). The accounted-for land (33,526,400 acres) included about 104,000 acres of what we term non-habitats — the hard (or gravel) surfaces of roads, railroads, and airstrips. To some extent the unaccounted acreage represents errors in our habitat estimates, but it also includes rural cemeteries, rural factories, and some parts of military reservations for which we had no data. In calculating Availability Factors, we have used only the accounted acreage, because unaccounted acreages differed greatly between regions.

The Availability Factor was calculated simply by dividing the acreage of each habitat (Table 3) into the total accounted acreage in the region, and then dividing the quotient by 10 to reduce numbers for convenient calculation. The value of the Availability Factor thus increases as the acreage decreases. The calculation was made on a regional basis, except in the case of the one gross habitat (gum-cypress forest) which is restricted to one region of the state. In this case, to emphasize the reduced availability of the habitat on a statewide basis, we calculated its Availability Factor by dividing the habitat acreage into the accounted acreage for the entire state. The numbers were rounded to the nearest whole number, excepting numbers lower than 1.6, which were rounded to the nearest one-tenth. As better acreage data become available, the factors can be refined for better accuracy; in any case the Availability Factors will have to be updated from time to time as habitat acreages change.

Changing Availability of Habitats

Changing availability refers to the rate at which the state or regional acreage of a given habitat is increasing or decreasing. In considering the habitat evaluation, it seemed important to take into account not only the present availability of the habitat, but its potential availability in the future. A habitat that is declining in acreage should get extra consideration in the environmental evaluation.

The changing availability was determined on the basis of the estimated acreage of the habitat at two points in time (Table 4). We used the most recent acreage data we could find and tried to find figures that spanned the most recent decade. Where such figures were not available, we tried to base the estimate on logical grounds and our own observations. For details, see the discussions of each habitat.

The Changing Availability Factor is merely the estimated percentage change in acreage of a given habitat for a decade. The factor is used as a positive value for declining habitats and a negative value for increasing habitats. It is an additive or subtractive modifier of the Availability Factor. In practice, if the Changing Availability Factor is equal to or exceeds the Availability Factor of an increasing habitat,

TABLE 4. — Changing Availability Factors for gross habitats in Illinois, based on estimated acreages of the habitats in the years listed.

Gross Habitat	Percentage of Change Per Decade				Years	Sources of Data and Remarks
	North	Central	South	State		
Bottomland forest						
Oak-gum-cypress	..	..	—25[a]	..	1962–1973	Essex & Gansner (1965), U.S. Dept. of Commerce (1972), and this paper.
Elm-ash-cottonwood	—56	—47	—35	..	"	"
Upland forest						
Oak-hickory	—41	—27	—17	..	"	"
Maple-beech	—49	—37	—26	..	...	No specific data. Use average for upland and bottomland forest.
Aspen	—41	—27	—17	..	...	No specific data. Use data for upland oak-hickory.
Pine forest	..	..	..	+8	1961–1973	U. S. Dept. of Agriculture (1968) and this paper.
Shrub areas	—43	—26	—16	..	1961–1973	"
Residential habitat	..	..	..	+19	1950–1960	U. S. Dept. of Commerce (1960, 1972).
Marshes	..	..	..	—22	1922–1954	Shaw & Fredine (1956).
Prairie	..	..	..	—6	1800–1970	King & Winters (1952) and this paper.
Ungrazed and fallow fields	..	..	..	—19	1954–1964	U. S. Dept. of Commerce (1972).
Pastures	..	..	..	—30	1959–1969	"
Hayfields	..	..	..	—50	"	"
Small-grain fields	..	..	..	—50	"	"
Row-crop fields	..	..	..	+27	"	"
Impoundments	..	..	..	+6	1963–1972	Lopinot (1973).

[a] A (—) sign indicates loss of acreage, a (+) sign indicates gain of acreage during the period of years. To calculate Changing Availability Factors, simply reverse the signs given in the table.

then the Final Availability Factor is not reduced below 0.1, as the full subtraction would result in a zero or a negative value and complicate further calculations. This exception applies only to row-crop habitat and residential habitat. The Final Availability Factor has been computed and is presented for the user's convenience in Table 5. It is the Availability Factor plus or minus the Changing Availability Factor. For example, an estimated 1,000 acres of maple-beech habitat over 50 years old exist in the northern region of Illinois (Table 3). This 1,000 acres divided into 8,314,600 acres (total accounted acreage in this region, see Table 3) gives a figure of 8,314.6, which, divided by 10, equals 831, the Availability Factor. Maple-beech acreage has been declining, with an estimated loss of 49 percent in a recent decade (Table 4); therefore, 49 is added to 831, giving a Final Availability Factor of 880 for this habitat (Table 5). The Final Availability Factor is used as a multiplier with the Replacement Cost Factor.

Acreage Factor

The Acreage Factor is an index of the amount of a given habitat in the impact area and, in use, is a percentage — the number of acres of the habitat divided by the number of acres in the impact area, the quotient expressed as a decimal, or 1.0 for a single-habitat impact area. The Acreage Factor is used as a multiplier in the computation of the Habitat Factor.

Table 5. — Final Availability Factors for habitats in three regions of Illinois, based on estimated acreages of the habitats in the state (Table 3). The Changing Availability Factor (Table 4) has been incorporated in these figures.

Gross Habitat	North	Central	South
Bottomland forest			
Oak-gum-cypress to 99 years	...	...	823
100+	...	...	424
Elm-ash-cottonwood to 29 years	95	68	41
30–59	82	61	39
60–99	130	86	45
100+	696	403	132
Upland forest			
Oak-hickory to 29 years	62	38	20
30–59	54	33	19
60–99	60	37	20
100+	120	67	28
Maple-beech to 49 years	805	543	284
50+	880	618	334
Aspen	171	549	...
Pine forest to 39 years	312	179	18
40+	1,031	595	76
Shrub areas	66	42	19
Residential habitat	0.1	0.1	0.1
Marshes	48	116	303
Prairie	163	928	687
Ungrazed and fallow fields	20	21	21
Pastures	31	31	31
Hayfields	52	53	52
Small-grain fields	52	52	51
Row-crop fields	0.1	0.1	0.1
Impoundments	8	11	2
Rivers and streams	8	10	8

The Faunal (Floral) Index

The Faunal Index, as we use it, is an avifaunal index. It consists of a sum of numerical values assigned to the nesting species that occupy a given area of habitat.

Living organisms do not differ in intrinsic value but because the environmental investigator must be concerned with the ultimate survival of all living components of a community, it may be necessary to emphasize the value of those in shortest supply or those populations that seem most vulnerable to extinction for whatever reason. On the other hand, there is a distinct danger of overemphasizing rarity as a criterion of value — deciding whether to recommend the preservation of an area in its natural state on the basis of the presence or absence of rare or endangered species. From such a viewpoint, no effort would be made to preserve populations until they became rare and endangered. In general, common populations have greater ecological effects than rare ones, and common populations should always be considered in the calculation of environmental value. Accordingly, in our point system for bird species the values we assigned are not strictly proportional to population. We assigned values to the species on two considerations: (1) a base value reflecting the state population of each species, and (2) a doubling of the base value for species with a high degree of specialization for a single gross habitat. The relationship between any organism and its habitat is always specialized, but there are apparent degrees of specialization, with some species appearing to be more particularly dependent upon a given habitat than others. Black terns, for example, do not nest except in a certain type of marsh, whereas catbirds nest in a variety of woody habitats. Because this specialization relates to survival, we have given it definite emphasis in the point system.

The base values we assigned are: (1) species with a state breeding population of 50,000 or more birds — 10 points; (2) species with 10,000–49,999 birds — 20 points; (3) species with 2,500–9,999 birds — 40 points; (4) species with 500–2,499 birds — 100 points; and (5) species with less than 500 nesting birds in the state are in a special category to be considered above and beyond any numerical value. Population estimates are based on our field work (Graber & Graber 1963 and later).

The weights of the point values for the Faunal Index were arbitrary, but were designed to have some reasonable relationship to the acreage values upon which the Faunal Index is finally standardized (see The Method in Practice). We tested different values and found that a base value of 1 for each bird species was insignificant in the final numerical evaluation. A base value of 10 proved to be significant and also convenient for ease of calculation. The point values for each species are given in Tables 6–12.

TABLE 6. — Faunal Index point values for breeding birds of forest habitats[a] in three regions of Illinois. The list includes only species that nest in the habitat, not those that only forage in the habitat. See text for explanation of value assignments.

Species	North		Central		South		Habitat Specialty
	Base	Special[b]	Base	Special	Base	Special	
Great blue heron	...	80	...	80	...	80	Bottomland
Green heron	20	...	20	...	20	...	Bottomland
Little blue heron	...	...	...	...	...	X[c]	Bottomland
Cattle egret	...	80	...	80	...	80	Bottomland
Great egret	...	200	...	200	...	200	Bottomland
Snowy egret	...	...	...	...	...	X[c]	Bottomland
Black-crowned night heron	40	...	40	...	40	...	...
Yellow-crowned night heron	...	200	...	200	...	200	Bottomland
Wood duck	20	...	20	...	20	...	...
Hooded merganser	...	200	...	200	...	200	Bottomland
Turkey vulture	40	...	40	...	40	...	...
Black vulture	...	...	...	...	100	...	...
Mississippi kite	...	...	...	...	...	X[c]	Bottomland
Sharp-shinned hawk	...	X[c]	...	...	...	...	...
Cooper's hawk	100	...	100	...	100	...	...
Red-tailed hawk	...	40	...	40	...	40	Upland
Red-shouldered hawk	...	80	...	80	...	80	Bottomland
Broad-winged hawk	100	...	100	...	100	...	...
Bald eagle	...	...	...	...	...	X[c]	...
Osprey	...	...	...	...	...	X[c]	...
Ruffed grouse	...	...	...	...	...	X[c]	...
Turkey	...	80	...	80	...	80	Extensive tracts
Mourning dove	10	...	10	...	10	...	...
Yellow-billed cuckoo	20	...	20	...	20	...	...
Black-billed cuckoo	40	...	40	...	40	...	...
Barn owl	...	X[c]	...	X[c]	...	X[c]	...
Screech owl	20	...	20	...	20	...	...
Great horned owl	20	...	20	...	20	...	...
Barred owl	20	...	20	...	20	...	...
Long-eared owl	...	X[c]	...	X[c]	...	X[c]	...
Saw-whet owl	...	X[c]	...	X[c]	...	X[c]	...
Chuck-will's widow	...	80	...	80	...	80	Upland
Whip-poor-will	...	40	...	40	...	40	Upland
Chimney swift	10	...	10	...	10	...	...
Ruby-throated hummingbird	20	...	20	...	20	...	...
Belted kingfisher	20	...	20	...	20	...	...
Yellow-shafted flicker	10	...	10	...	10	...	...
Pileated woodpecker	20	...	20	...	20	...	...
Red-bellied woodpecker	10	...	10	...	10	...	...
Red-headed woodpecker	10	...	10	...	10	...	...
Yellow-bellied sapsucker	...	200	...	200	...	...	Bottomland
Hairy woodpecker	10	...	10	...	10	...	...
Downy woodpecker	10	...	10	...	10	...	...
Great crested flycatcher	10	...	10	...	10	...	...
Eastern phoebe	20	...	20	...	20	...	...
Acadian flycatcher	...	20	...	20	...	20	Bottomland
Least flycatcher	100	...	100	...	...	...	...
Eastern wood pewee	10	...	10	...	10	...	...
Blue jay	10	...	10	...	10	...	...
Common crow	10	...	10	...	10	...	...
Fish crow	...	...	...	...	...	80	Bottomland
Black-capped chickadee	10	...	10	...	10	...	...
Carolina chickadee	...	...	10	...	10	...	...
Tufted titmouse	10	...	10	...	10	...	...
White-breasted nuthatch	20	...	20	...	20	...	...
Red-breasted nuthatch	...	X[c]	...	...	...	...	Conifers
Brown creeper	...	200	...	200	...	200	Bottomland
House wren	10	...	10	...	10	...	...
Carolina wren	10	...	10	...	10	...	...

(Table 6 continued on page 10.)

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[a] Includes all types of forest (see Table 3) and forest edge as well as interior.

[b] Species with values in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[c] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

TABLE 6. — Continued

Species	North		Central		South		Habitat Specialty
	Base	Special[b]	Base	Special	Base	Special	
Gray catbird	10	...	10	...	10	...	...
Brown thrasher	10	...	10	...	10	...	...
American robin	10	...	10	...	10	...	...
Wood thrush	10	...	10	...	10	...	...
Veery	...	200	...	200	...	...	Bottomland
Eastern bluebird	10	...	10	...	10	...	...
Blue-gray gnatcatcher	10	...	10	...	10	...	...
Cedar waxwing	40	...	40	...	40	...	...
White-eyed vireo	10	...	10	...	10	...	...
Yellow-throated vireo	10	...	10	...	10	...	...
Red-eyed vireo	10	...	10	...	10	...	...
Warbling vireo	...	40	...	40	...	40	Bottomland
Black-and-white warbler	...	80	...	80	...	80	Upland
Prothonotary warbler	...	40	...	40	...	40	Bottomland
Swainson's warbler	...	...	...	...	...	200	Bottomland
Worm-eating warbler	...	40	...	40	...	40	Upland ravine
Nashville warbler	...	X[c]	...	...	...	...	...
Parula warbler	...	40	...	40	...	40	Bottomland
Cerulean warbler	...	20	...	20	...	20	Bottomland
Yellow-throated warbler	...	...	...	80	...	80	Bottomland
Chestnut-sided warbler	40	...	...	...	...	...	...
Pine warbler	...	...	...	...	...	200	Pines
Ovenbird	20	...	20	...	20	...	...
Louisiana waterthrush	...	40	...	40	...	40	Forest rill
Kentucky warbler	10	...	10	...	10	...	...
Yellow-breasted chat	10	...	10	...	10	...	...
Hooded warbler	...	...	20	...	20	...	...
American redstart	...	20	...	20	...	20	Bottomland
Baltimore oriole	20	...	20	...	20	...	...
Common grackle	10	...	10	...	10	...	...
Brown-headed cowbird	10	...	10	...	10	...	...
Scarlet tanager	20	...	20	...	20	...	...
Summer tanager	10	...	10	...	10	...	...
Cardinal	10	...	10	...	10	...	...
Rose-breasted grosbeak	10	...	10	...	10	...	...
Indigo bunting	10	...	10	...	10	...	...
Rufous-sided towhee	10	...	10	...	10	...	...
Field sparrow	10	...	10	...	10	...	...

These tables include virtually all of the known breeding species of birds in Illinois, even rarities that have been known to nest in the state within recent decades but which may now be extirpated (e.g., the peregrine falcon). Such species are included because of the possibility that they may still be found nesting in the state. Some of the species listed in Table 12 are not listed in any other table because they have special nesting habitats or special nest-site requirements and may be found in one or more of the gross habitats of our habitat classification. When these species are found nesting in an impact area, they are counted in the same way as any other species in whatever gross habitat(s) they are found.

We made our species lists as complete as possible, but occasionally an investigator may find a species that we have not included in our list for that habitat. In such cases the species is counted, of course, and the investigator should merely refer to the other habitat tables to ascertain the assigned value for the species in question. Such an occurrence is most likely in the case of residential habitat, as many species not listed in Table 8 occasionally nest in this habitat.

We elected not to put additional weight on the *extremely* rare populations, such as the last known colony of double-crested cormorants in the state. Where the impact area in question involves such last remnants, the mere presence of such a population becomes the overriding consideration as a value beyond the computed Habitat and Faunal Indexes. This is as true for other living things as it is for birds, and the impact investigator must make every effort to find such populations, both plant and animal, on every impact area. In the faunal lists (Tables 6–12) we have marked such populations of Illinois birds.

The question arises: Why be concerned with the loss of populations in Illinois when all of the species are represented elsewhere? There are at least two important reasons: (1) The alteration of habitats that is occurring in Illinois is also occurring elsewhere. The inevitable result, if each state allows its own populations to slip away, is the ultimate extinction of species by default. (2) Every species is comprised of numerous populations, and the genetic breadth of the species is the sum of the genetic breadth of the populations. Some of the populations are morphologically distinct, others not, but all are probably unique if only in the problems they face. Therefore, in the conservation of species we must be concerned for the welfare of all the populations that comprise the species.

In any consideration of population survival we must be particularly aware of endemism. In Illinois the only possibly endemic bird population of which we know is the Mississippi kite of the southwestern part of the state, primarily near the Mississippi valley from St. Louis south. The endemism in this case may be more apparent than real. Presently the distribution records imply that this kite population is isolated during the nesting season from the more sub-

TABLE 7. — Faunal Index point values for breeding birds of shrub habitats[a] in three regions of Illinois. The list includes only species that nest in the habitat, not those that only forage in the habitat. See text for explanation of the value assignments.

Species	North		Central		South		Habitat Specialty
	Base	Special[b]	Base	Special	Base	Special	
Green heron	20	...	20	...	20	...	...
Bobwhite	10	...	10	...	10	...	...
American woodcock	...	40	...	40	...	40	Shrub areas
Mourning dove	10	...	10	...	10	...	...
Yellow-billed cuckoo	20	...	20	...	20	...	...
Black-billed cuckoo	40	...	40	...	40	...	...
Downy woodpecker	10	...	10	...	10	...	...
Eastern kingbird	...	20	...	20	...	20	Savannah
Western kingbird	...	200	...	200	...	200	Savannah
Willow flycatcher	...	40	...	40	...	40	Shrub
Least flycatcher	100	...	100	...	100	...	...
Blue jay	10	...	10	...	10	...	...
Black-capped chickadee	10	...	10	...	10	...	...
Carolina chickadee	...	...	10	...	10	...	...
Tufted titmouse	10	...	10	...	10	...	...
House wren	10	...	10	...	10	...	...
Bewick's wren	40	...	40	...	40	...	...
Carolina wren	10	...	10	...	10	...	...
Mockingbird	10	...	10	...	10	...	...
Gray catbird	10	...	10	...	10	...	...
Brown thrasher	10	...	10	...	10	...	...
American robin	10	...	10	...	10	...	...
Eastern bluebird	10	...	10	...	10	...	...
Blue-gray gnatcatcher	10	...	10	...	10	...	...
Loggerhead shrike	...	80	...	80	...	80	Shrub
White-eyed vireo	10	...	10	...	10	...	...
Bell's vireo	...	80	...	80	...	80	Shrub
Golden-winged warbler	...	X[c]	...	...	...	...	Shrub areas
Blue-winged warbler	...	80	...	80	...	80	Shrub areas
Yellow warbler	...	40	...	40	...	40	Shrub areas
Prairie warbler	...	80	...	80	...	80	Shrub areas
Mourning warbler	...	X[c]	...	...	...	...	Wet shrub areas
Common yellowthroat	10	...	10	...	10	...	...
Yellow-breasted chat	10	...	10	...	10	...	...
Red-winged blackbird	10	...	10	...	10	...	...
Orchard oriole	...	20	...	20	...	20	Shrub
Brewer's blackbird	...	X[c]	...	...	...	...	...
Common grackle	10	...	10	...	10	...	...
Brown-headed cowbird	10	...	10	...	10	...	...
Cardinal	10	...	10	...	10	...	...
Blue grosbeak	...	80	...	80	...	80	Shrub
Indigo bunting	10	...	10	...	10	...	...
Dickcissel	10	...	10	...	10	...	...
American goldfinch	...	20	...	20	...	20	Shrub
Rufous-sided towhee	10	...	10	...	10	...	...
Vesper sparrow	10	...	10	...	10	...	...
Lark sparrow	20	...	20	...	20	...	...
Bachman's sparrow	...	...	...	X[c]	...	X[c]	Shrub areas
Chipping sparrow	20	...	20	...	20	...	...
Field sparrow	10	...	10	...	10	...	...
Song sparrow	10	...	10	...	10	...	...

[a] Includes all types of shrub habitat, including linear and hedges, but excludes shrubs in residential areas.

[b] Species in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[c] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

Table 8. — Faunal Index point values for breeding birds of residential habitats, including new suburban and old residential habitats in urban and rural areas. The list includes only species that nest in the habitat, not those that only forage in the habitat. See text for explanation of value assignments.

Species	North		Central		South		Habitat Specialty
	Base	Special[a]	Base	Special	Base	Special	
Wood duck	20	...	20	...	20	...	...
Sparrow hawk	...	40	...	40	...	40	Savannah
Mourning dove	10	...	10	...	10	...	...
Barn owl	...	X[b]	...	X[b]	...	X[b]	...
Screech owl	20	...	20	...	20	...	...
Common nighthawk	...	40	...	40	...	40	Flat roofs
Chimney swift	10	...	10	...	10	...	...
Yellow-shafted flicker	10	...	10	...	10	...	...
Red-bellied woodpecker	10	...	10	...	10	...	...
Red-headed woodpecker	10	...	10	...	10	...	...
Downy woodpecker	10	...	10	...	10	...	...
Eastern kingbird	...	20	...	20	...	20	Savannah
Great crested flycatcher	10	...	10	...	10	...	...
Eastern phoebe	20	...	20	...	20	...	...
Eastern wood pewee	10	...	10	...	10	...	...
Horned lark	10	...	10	...	10	...	...
Barn swallow	...	20	...	20	...	20	Buildings
Purple martin	...	20	...	20	...	20	Bird houses
Blue jay	10	...	10	...	10	...	...
Black-capped chickadee	10	...	10	...	10	...	...
Carolina chickadee	...	...	10	...	10	...	...
Tufted titmouse	10	...	10	...	10	...	...
White-breasted nuthatch	20	...	20	...	20	...	...
Red-breasted nuthatch	...	X[b]	...	...	...	...	Conifers
House wren	10	...	10	...	10	...	...
Bewick's wren	40	...	40	...	40	...	...
Carolina wren	10	...	10	...	10	...	...
Mockingbird	10	...	10	...	10	...	...
Gray catbird	10	...	10	...	10	...	...
Brown thrasher	10	...	10	...	10	...	...
American robin	10	...	10	...	10	...	...
Wood thrush	10	...	10	...	10	...	...
Eastern bluebird	10	...	10	...	10	...	...
Cedar waxwing	40	...	40	...	40	...	...
Warbling vireo	...	40	...	40	...	40	Bottomland
Baltimore oriole	20	...	20	...	20	...	...
Common grackle	10	...	10	...	10	...	...
Brown-headed cowbird	10	...	10	...	10	...	...
Cardinal	10	...	10	...	10	...	...
Chipping sparrow	20	...	20	...	20	...	...
Song sparrow	10	...	10	...	10	...	...

[a] Species with values in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[b] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

stantial populations to the south and west. The kite is a strongly migratory species, and, depending upon its homing characteristics, there is the annual possibility of genetic exchange between Illinois birds and other populations. Until more complete information is available, the Illinois kite population can be considered endemic. We have not put an extraordinary value on the kite in our faunal valuation, feeling that the presence of any endemic population of any organism, plant or animal, on an impact area is an overriding factor beyond the index values calculated by our method.

Species of accidental occurrence in a habitat or a region we consider to have zero value, as there is no indication that such a population is dependent upon this state for survival or that it has any significant effect upon the state. We exclude introduced bird species from our calculation of environmental value, because we feel that the evaluation should be based on native species.

Though we have used birds and their gross habitats in our evaluation method, other faunas and floras can be used in exactly the same way, provided they are represented in all the gross habitats. It is not necessary that a particular taxonomic category of organisms — for example, a Class of vertebrates (birds) or an Order of insects (Lepidoptera) — be used. More important is the number of species in the group or groups. If another faunal group (than birds) or floral group is used in the evaluation, the number of species in that group should be compared with the number of species (about 180) in the bird fauna that we have used. The value placed on each species can then be related to the values placed on the bird fauna. If the new fauna (flora) has 360 species, for example, then the base value of each species should be set at 5 instead of 10 as used for bird species, and the values for specialization and rarity would be comparably reduced. By this means the standard upon which the evaluation is based is kept the same regardless of what faunal or floral groups are used.

If more than one faunal (floral) group is used in the evaluation, the impact area will be represented by a series of Faunal (Floral) Indexes.

As an indication of the number of bird species that might be found on a given acreage of a particular gross habitat in Illinois we refer the reader to Fig. 3–7. These figures show what could be called "species-area curves" for birds in different Illinois habitats. In general, the number of species seen in a given habitat increases as the amount of habitat censused increases. Our figures apply only to species that nest in a particular habitat, not to species that only forage in the habitat.

The curves were constructed from data collected

TABLE 9. — Faunal Index point values for breeding birds of marshes[a] in three regions of Illinois. The list includes only species that nest in the habitat, not those that only forage in the habitat. See text for explanation of value assignments.

Species	North		Central		South		Habitat Specialty
	Base	Special[b]	Base	Special	Base	Special	
Pied-billed grebe	...	200	...	200	...	200	Marsh
Least bittern	...	80	...	80	...	80	Marsh
American bittern	...	200	...	200	...	200	Marsh
Canada goose	...	80	...	80	...	80	Marsh areas
Mallard	...	40	...	40	...	40	Marsh areas
Black duck	...	200	...	...	...	...	Marsh areas
Pintail	...	X[c]	...	...	...	...	Marsh areas
Green-winged teal	...	X[c]	...	X[c]	...	...	Marsh areas
Blue-winged teal	...	80	...	80	...	80	Marsh areas
American wigeon	...	X[c]	...	...	...	...	Marsh areas
Shoveler	...	X[c]	...	...	...	...	Marsh areas
Redhead	...	X[c]	...	...	...	...	Marsh areas
Canvasback	...	X[c]	...	...	...	...	Marsh areas
Lesser scaup	...	X[c]	...	...	...	...	Marsh areas
Ruddy duck	...	X[c]	...	...	...	...	Marsh areas
Marsh hawk	...	200	...	200	...	...	Marsh areas
King rail	...	80	...	80	...	80	Marsh
Virginia rail	...	80	...	80	...	80	Marsh
Sora	...	80	...	80	...	80	Marsh
Black rail	...	X[c]	...	X[c]	...	X[c]	Marsh
Common gallinule	...	200	...	200	...	200	Marsh
Purple gallinule	...	...	...	...	...	X[c]	Marsh
American coot	...	80	...	80	...	80	Marsh
Killdeer	10	...	10	...	10	...	...
Common snipe	...	X[c]	...	...	...	...	...
Spotted sandpiper	...	80	...	80	...	80	Water edge
Wilson's phalarope	...	X[c]	...	...	...	...	...
Forster's tern	...	X[c]	...	...	...	...	Marsh
Common tern	...	X[c]	...	...	...	...	Water edge
Black tern	...	80	...	80	...	...	Marsh
Long-billed marsh wren	...	80	...	80	...	...	Marsh
Short-billed marsh wren	20	...	20	...	20	...	...
Common yellowthroat	10	...	10	...	10	...	...
Yellow-headed blackbird	...	80	...	...	...	...	Marsh
Red-winged blackbird	10	...	10	...	10	...	...
Brewer's blackbird	...	X[c]	...	...	...	...	...
Common grackle	10	...	10	...	10	...	...
Brown-headed cowbird	10	...	10	...	10	...	...
Savannah sparrow	10	...	10	...	...	...	...
Leconte's sparrow	...	X[c]	...	...	...	...	Wet meadow, marsh
Henslow's sparrow	...	80	...	80	...	80	Meadow
Swamp sparrow	...	40	...	40	...	...	Marsh
Song sparrow	10	...	10	...	10	...	...

[a] Includes marshes of all types, from cattails and scirpus to lotus beds and wet meadows.

[b] Species with values in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[c] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

TABLE 10. — Faunal Index point values for breeding birds of grasslands, including dry prairie, ungrazed grass, fallow fields, pastures, and hayfields. The list includes only species that nest in the habitat, not those that only forage in the habitat. See text for explanation of value assignments.

Species	North		Central		South		Habitat Specialty
	Base	Special[a]	Base	Special	Base	Special	
Greater prairie chicken	...	...	...	...	...	X[b]	Grassland
Bobwhite	10	...	10	...	10	...	...
Killdeer	10	...	10	...	10	...	...
Upland sandpiper	...	80	...	80	...	80	Grassland
Mourning dove	10	...	10	...	10	...	...
Short-eared owl	...	X[b]	...	X[b]	...	X[b]	Grassland
Common nighthawk	20	...	20	...	20	...	...
Horned lark	10	...	10	...	10	...	...
Short-billed marsh wren	20	...	20	...	20	...	...
Common yellowthroat	10	...	10	...	10	...	...
Bobolink	...	20	...	20	...	...	Hayfields
Eastern meadowlark	...	20	...	20	...	20	Grassland
Western meadowlark	...	20	...	20	...	...	Grassland
Red-winged blackbird	10	...	10	...	10	...	...
Brown-headed cowbird	10	...	10	...	10	...	...
Dickcissel	10	...	10	...	10	...	...
Savannah sparrow	...	20	...	20	...	...	Grassland
Grasshopper sparrow	...	20	...	20	...	20	Grassland
Henslow's sparrow	...	80	...	80	...	80	Grassland
Vesper sparrow	10	...	10	...	10	...	...
Lark sparrow	20	...	20	...	20	...	...
Field sparrow	10	...	10	...	10	...	...
Song sparrow	10	...	10	...	10	...	...

[a] Species with values in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[b] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

TABLE 11. — Faunal Index point values for breeding birds of small-grain fields and row-crop fields in three regions of Illinois. The list includes only species that nest in the habitats, not those that only forage in the habitats. Those marked with (R) are known to nest in row-crop fields. See text for explanation of value assignments.

Species	North	Central	South
	Base	Base	Base
Bobwhite	10	10	10
Killdeer (R)	10	10	10
Horned lark (R)	10	10	10
Bobolink	10	10	10
Eastern meadowlark	10	10	10
Red-winged blackbird	10	10	10
Brown-headed cowbird	10	10	10
Grasshopper sparrow	10	10	10
Vesper sparrow (R)	10	10	10

using the strip census method of censusing birds (Graber & Graber 1963). As the strip censuses were made on straight-line transects, habitats encountered varied from small tracts of an acre or less to 50 acres or more. We constructed the curves by arranging the bird census data from the smallest-sized area censused to the largest. We then summed both the acreages and the numbers of different species of birds and plotted the cumulative sums on graph paper (Fig. 3–7). Because our data are from quantitative strip censuses, they are not strictly comparable to the qualitative censuses that the impact investigator will make, but the figures are at least roughly indicative of what the investigator can expect to find. We did not have sufficient samples to construct curves for all habitats, but the habitats included represent most of the grassland and woody habitat faunas. The most serious omission is marsh habitat. We did not plot a curve for row-crop habitat, as it usually supports only two or three nesting species even on a very large acreage. A discrepancy may exist between the number of bird species accounted for in our habitat tables (Tables 6–12) and the number in the illustrations. This discrepancy occurs because the tables have a complete list of species for each habitat, whereas the figures include only the species most likely to be found in the habitat.

THE GROSS HABITATS

We have considered the Illinois bird habitats in their gross forms. Every gross habitat may include numerous microhabitats or niches, but in any consideration of whether the habitats in an area shall be altered, it is axiomatic that the niches will not survive the destruction of the gross habitats. Thus, from a practical standpoint investigators of environmental impact can concern themselves with habitats in their gross forms. To some degree the avifaunal variety, which is taken into account in our evaluation method, is a measure of, or at least an index to, the number of niches.

Anyone who has done much biological field work knows that habitats are not always neatly compartmentalized and defined. Neither do biologists always agree on how habitats should be defined or what they should be called. In deciding what habitat classificaion to use in the present case we were governed to some extent by certain concerns outside the biological problems. We felt obligated to keep the classification as simple as possible in the interest of the

Table 12. — Faunal Index point values for breeding birds of special habitats not included in the gross habitat classifiations in three regions of Illinois. The list includes only species that nest in each habitat, not those that only forage in the habitat. See text for explanation of value assignments.

Species	North		Central		South		Nesting Site or Habitat
	Base	Special[a]	Base	Special	Base	Special	
Swainson's hawk	...	X[b]	...	...	...	...	Savannah
Peregrine falcon	...	X[b]	...	X[b]	...	X[b]	High cliffs
Sparrow hawk	...	40	...	40	...	40	Savannah
Piping plover	...	X[b]	...	...	...	...	Lake Michigan beach
Spotted sandpiper	...	80	...	80	...	80	Water edge
Ring-billed gull	...	X[b]	...	...	...	...	Water edge, sand bars
Least tern	...	X[b]	...	X[b]	...	X[b]	Sand bars
Belted kingfisher	20	...	20	...	20	...	Stream and other erosion banks
Tree swallow	20	...	20	...	20	...	Dead stumps
Bank swallow	10	...	10	...	10	...	Stream and other erosion banks
Rough-winged swallow	10	...	10	...	10	...	Stream and other erosion banks
Cliff swallow	20	...	20	...	20	...	Rock cliffs and culverts

[a] Species with values in the special columns are found as nesting birds primarily in only one gross habitat. Their base values have been doubled.

[b] Indicates species in a very special category with a state breeding population of less than 500 birds. They are to be considered above and beyond the numerical value in a class by themselves.

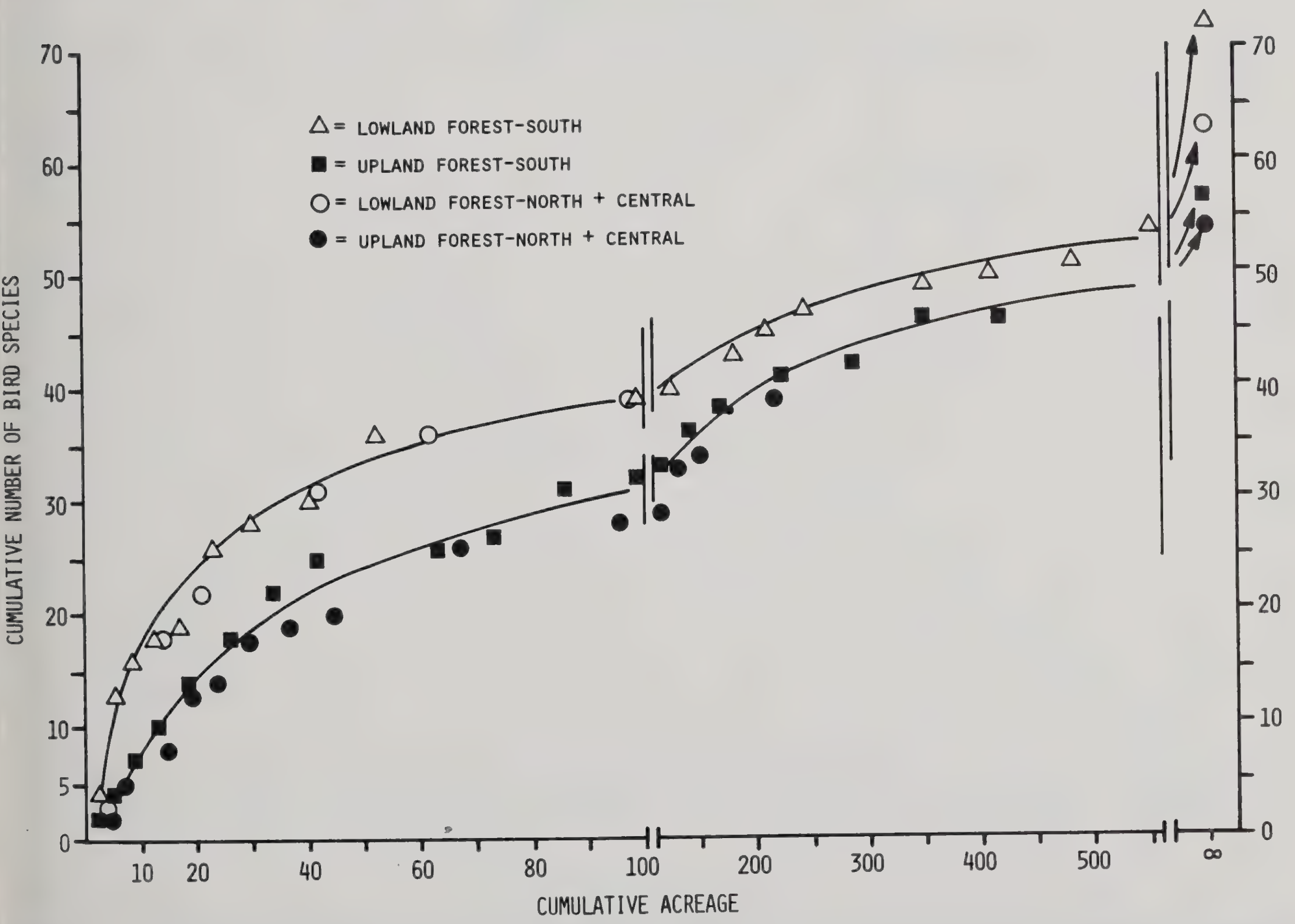

Fig. 3. — Numbers of bird species found nesting in different-sized tracts of upland and lowland forest in the three regions (Fig. 2) of Illinois.

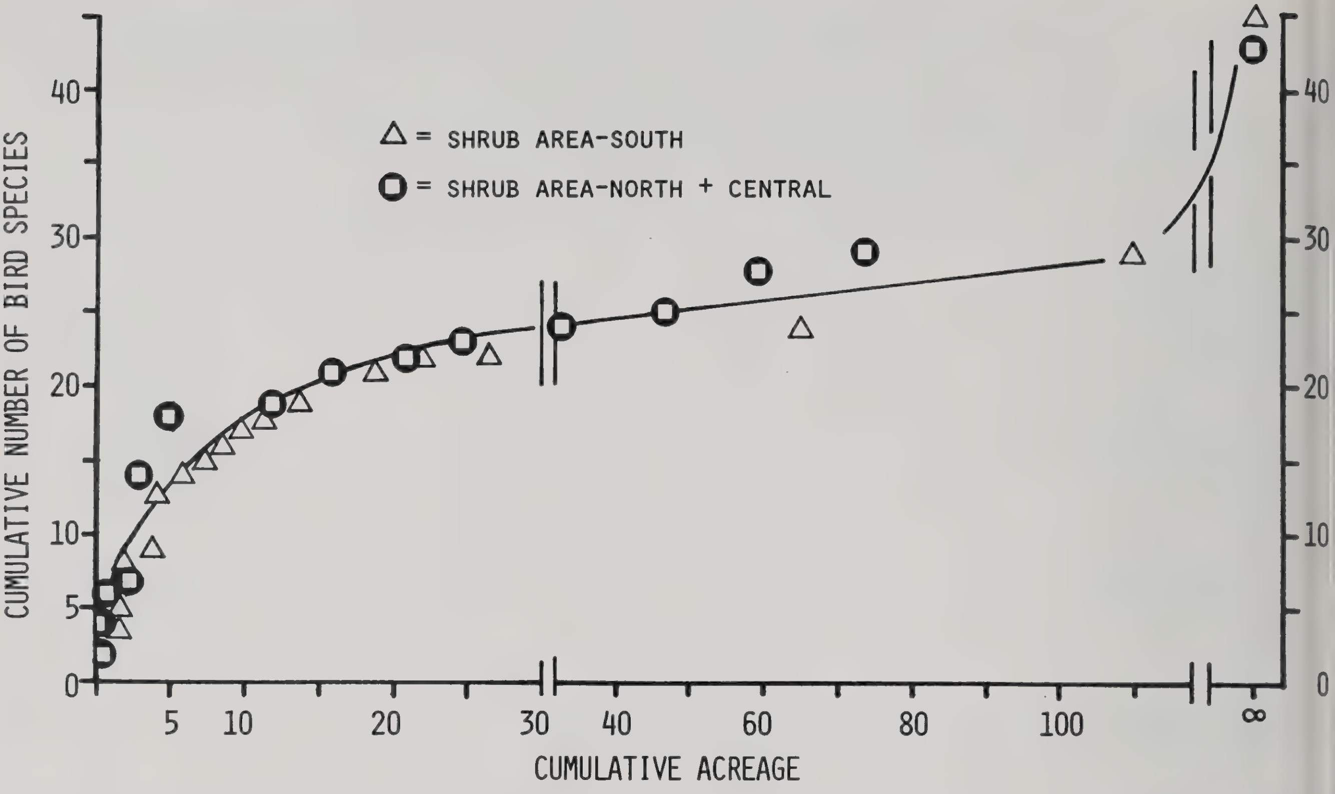

Fig. 4. — Numbers of bird species found nesting in different-sized tracts of shrub habitat in the three regions (Fig. 2) of Illinois.

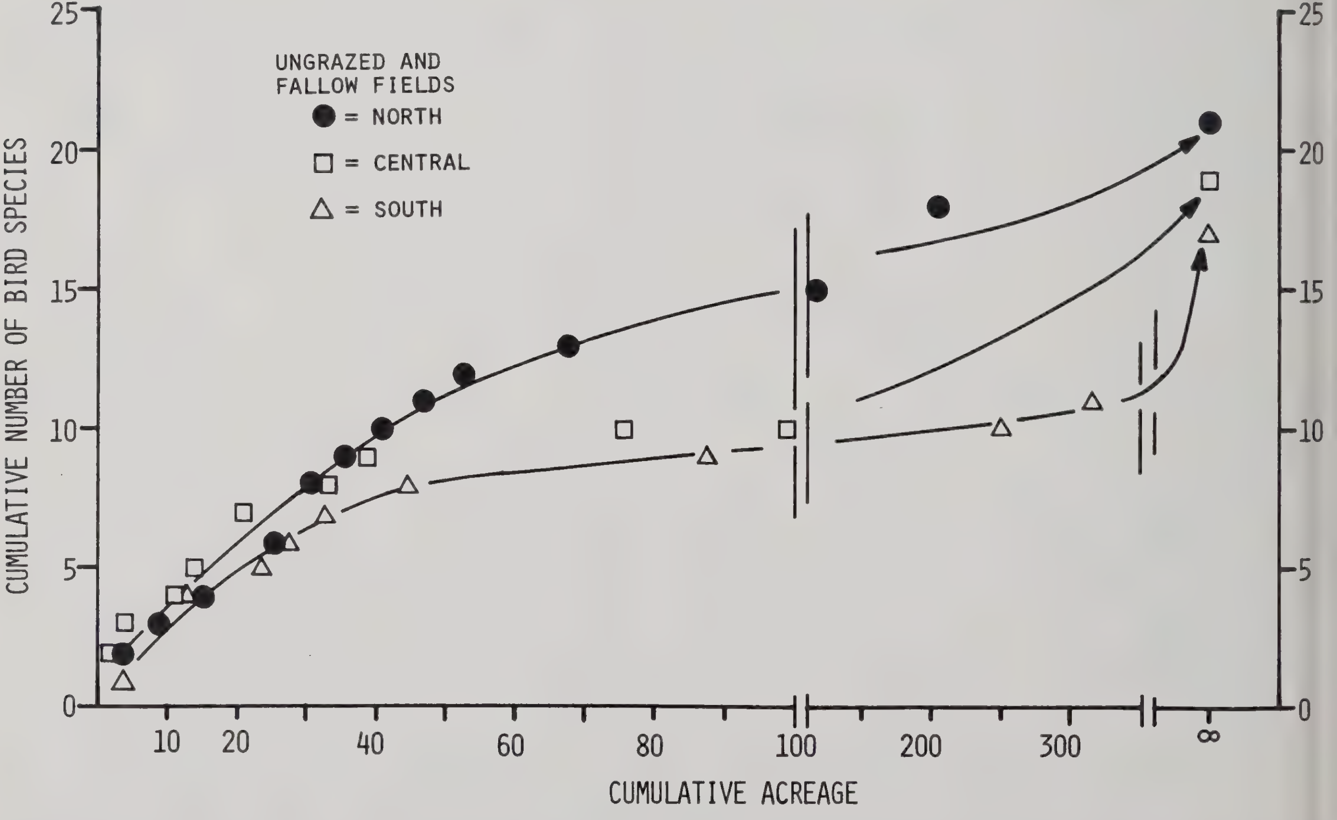

Fig. 5. — Numbers of bird species found nesting in different-sized tracts of ungrazed and fallow fields in the three regions (Fig. 2) of Illinois.

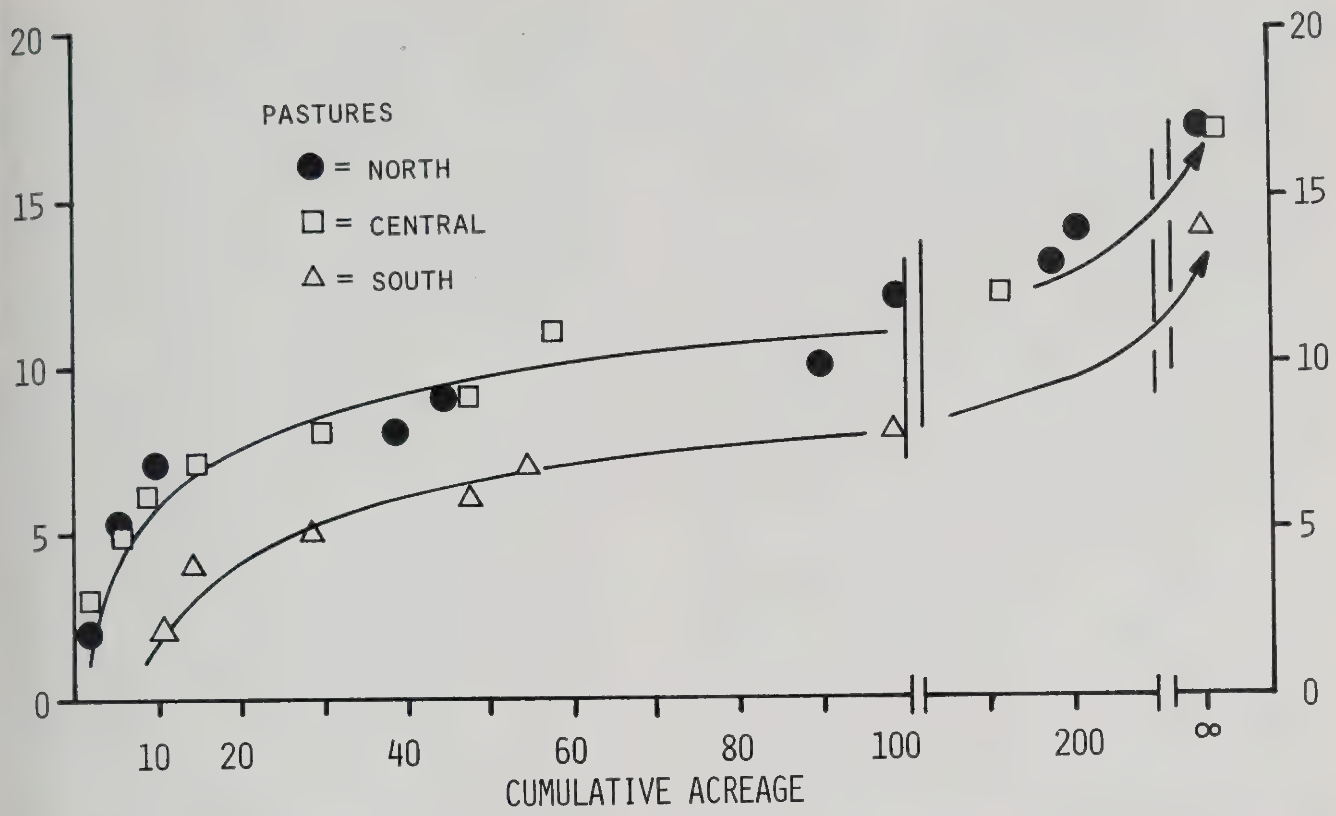

Fig. 6. — Numbers of bird species found nesting in different-sized tracts of pastured grasslands in the three regions (Fig. 2) of Illinois.

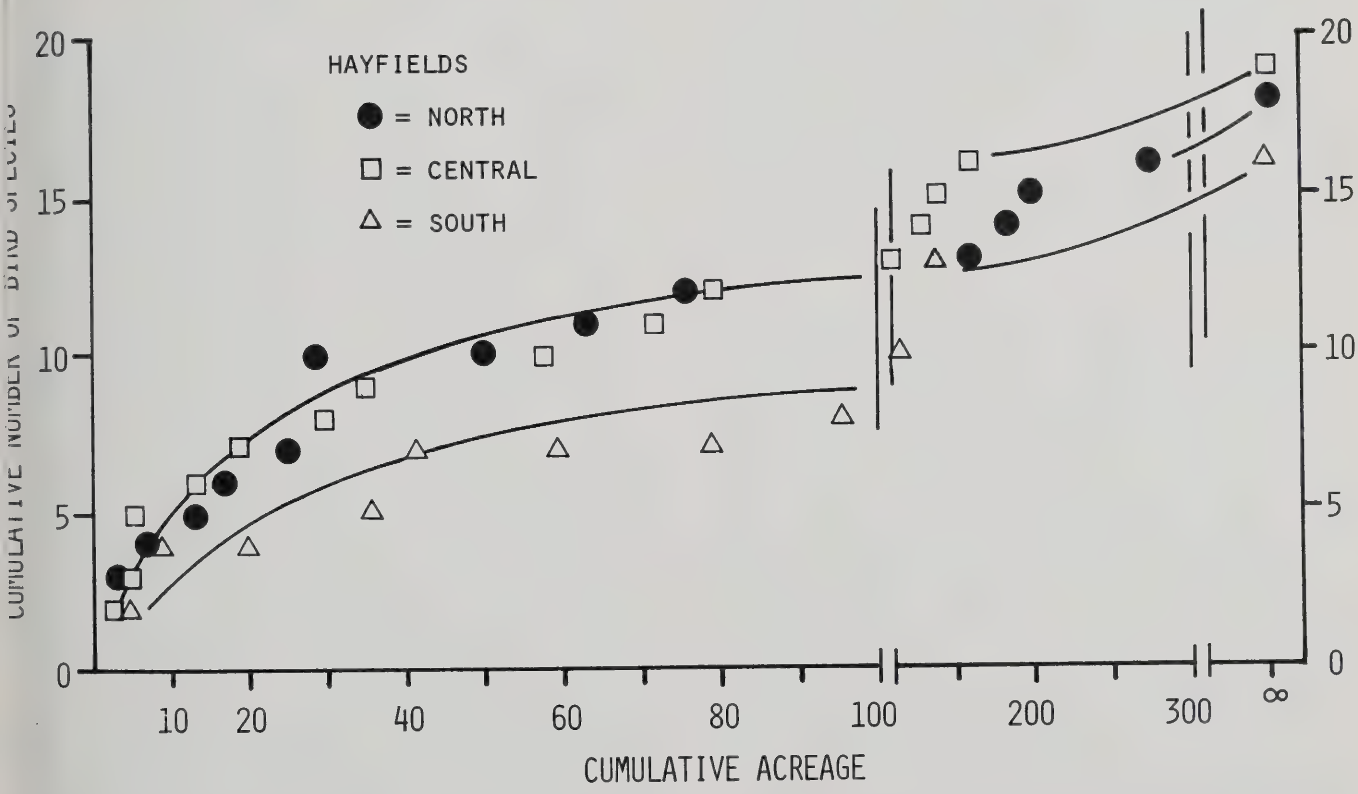

Fig. 7. — Numbers of bird species found nesting in different-sized tracts of hay land in the three regions (Fig. 2) of Illinois.

wide variety of investigators who might use the system. Another consideration was the matter of acquiring acreage data for the habitats. The habitat divisions could not be more refined than the available acreage data, as acreage data are vital to the system. Even our gross classification required some tenuous estimates in this regard. We also had to be able to interpret the habitat classification in terms of bird populations and account for all or nearly all of the species.

In general, we have used available published classifications of habitats that provided acreage data. In some cases we have made our own modifications for reasons that are explained. Our definitions of the gross habitats and the sources of data we used are given in the following accounts. In considering the floral aspect of habitats, we are forced to deal with exotic and adventitious species, as some gross habitats (row crops, hayfields, pine plantations) are composed almost entirely of introduced plants. These habitats are often inferior as substrates for bird populations, probably because they lack floral variety and perhaps to some degree because of their exotic character.

Forest Habitats

The classification of gross forest habitats (Table 3) is that of Essex & Gansner (1965) because this reference was the source of most of the acreage data for these habitats.

The oak-gum-cypress forest includes the wettest lowland woods (swamps) and occurs only in the southern part of the state. By Essex & Gansner's definition, 50 percent or more of the trees in this type are gum (*Nyssa aquatica*), cypress (*Taxodium distichum*), and/or oaks, the most characteristic being pin oak (*Quercus palustris*), basket oak (*Q. michauxii*), overcup oak (*Q. lyrata*), Shumard's oak (*Q. shumardii*), and cherrybark oak (*Q. falcata pagodaefolia*).

The other bottomland forest type occurs in all regions of the state. It is characterized by Essex & Gansner as consisting of 50 percent or more elm (*Ulmus americana*), ash (*Fraxinus* spp.), or cottonwood (*Populus deltoides*), and it is found particularly on the floodplains of rivers and streams. With the dying of elms from Dutch elm disease, elms have become less important in this association. Other representative tree species of this forest type in various parts of the state are silver maple (*Acer saccharinum*), swamp white oak (*Q. bicolor*), bur oak (*Q. macrocarpa*), pecan (*Carya illinoensis*), bitternut hickory (*C. cordiformis*), hackberry (*Celtis occidentalis*), red maple (*A. rubrum*), river birch (*Betula nigra*), and sycamore (*Platanus occidentalis*). This association is present even on relatively small hill streams if they have definite floodplains.

The oak-hickory forest type is described as woodland in which 50 percent or more of the trees are upland oaks — white (*Q. alba*), black (*Q. velutina*), red (*Q. rubra*), Spanish (*Q. falcata*), chestnut (*Q. muhlenbergii*), blackjack (*Q. marilandica*), and post (*Q. stellata*) — and hickories, such as pignut (*C. glabra*), shagbark (*C. ovata*), and mockernut (*C. tomentosa*). Sugar maple (*A. saccharum*), black walnut (*Juglans nigra*), and black locust (*Robinia pseudoacacia*) are also characteristic tree species of this forest type. We have also included in this acreage category oak-pine forests in which the forest is primarily deciduous, as the fauna in such areas is essentially the deciduous forest fauna.

As a practical matter the two large forest types — elm-ash-cottonwood and upland oak-hickory, which together comprise more than 95 percent of all Illinois forest habitat — can usually be identified on the basis of topography even before their vegetation is studied.

Left undisturbed, plants will invade bare ground, and over a period of years the kinds of plants will gradually change in a predictable sequence known as succession. Finally a stage is reached where conspicuous change is no longer evident, and this stage of more or less stable vegetation is called climax. Sometimes continuing disturbance or particular soil or topographic conditions exist that prevent the succession from proceeding to the ultimate climax association for the region and climate. Then one of the successional stages will appear to be stable in a local area.

Clements & Shelford (1939) described five different woodland successions, and Shelford (1954) gives a table showing the time required for the development of the various associations, such as those occurring in bottomland forest in the southern part of Illinois. From these data we can predict the dominant species of bottomland forest on a time schedule. Bottomland woods less than 30 years of age will be largely willow (*Salix* sp.) or cottonwood or a mixture of these species. Those woodlands 30–65 years old will be cottonwood with younger silver maple, ash, and hackberry coming in as the shade-intolerant willow dies out. The 60- to 100-year-old bottomland forest will be predominantly hackberry-ash-silver maple with some elm and oak saplings. After 200 years, one begins to find an elm-oak-hickory association. This type is followed by regional or site climaxes for Illinois, maple-basswood (*Acer saccharum-Tilia americana*), oak-hickory (*Quercus* sp.-*Carya* sp.), or maple-beech (*Acer saccharum-Fagus grandifolia*). Because of the slow growth rate of beech, forests with large beech trees are known to be among Illinois' oldest woodlands.

The succession for upland woods proceeds from shrubs, after 25–40 years following the abandonment of cropland, to a tree growth of shade-intolerant species, i.e., tree species whose early development is inhibited by shade, such as elms, black cherry (*Prunus serotina*), hawthorns (*Crataegus* sp.) (Beckwith

1954), persimmon (*Diospyros virginiana*), and sassafras (*Sassafras albidum*) (Bazzaz 1968). After 60–100 years an oak-hickory woodland develops, and after 150–200 years in suitable situations a maple-beech climax may arise. In sand areas around Lake Michigan an initial growth of cottonwood may be followed by pines (*Pinus banksiana* and *P. strobus*), which are followed by oak or oak-hickory (Steyermark 1940). Aspen (*Populus grandidentata* and *P. tremuloides*) woodland occurs as forest edge or develops as a result of disturbance (removal of the canopy) and is relatively short-lived, being replaced as a canopy of other species develops.

Various local disturbances often lead to a number of different-aged associations within a small area. Hence, each woodland is distinctive in its constitution but can be fitted into the gross habitat classification.

With the exception of relatively few acres of naturally occurring pines, which are often a small part of a deciduous forest, most of the pine stands in Illinois are managed plantations, often of introduced species. There are only three or four native species — white pine (*Pinus strobus*), jack pine (*P. banksiana*), shortleaf pine (*P. echinata*), and possibly red pine (*P. resinosa*) in very restricted numbers. Pine plantations have consistently poor faunas. Most of the stands are relatively young (under 40 years) and if left undisturbed, will eventually be replaced by native deciduous trees.

The availability data (acreage) of forest habitats were based initially on Essex & Gansner (1965). In using the 1962 acreages of Essex & Gansner, including their stand-age data, we considered the noncommercial forest acreage (110,000 acres) to have the same habitat and age classification as the commercial forest acreage (3,761,400 acres) that they account for. Though this assumption is not strictly true, it was the only logical basis on which to account for the noncommercial forest.

From the 1962 base we estimated the 1973 acreages from data in the *1969 Census of Agriculture* (U. S. Department of Commerce 1972), which indicated that woodland on farms — most of the Illinois forest — declined at the rate of 2.6 percent per year in the southern counties, 2.7 percent in the central counties, and 4.2 percent in the north between 1964 and 1969. As the increasing human population of the world depleted U. S. grain reserves, the prices of farm products began to rise, and farmers began sacrificing forest, especially flatland forest, to increase cropland. The rate of change may have been greater after 1969 than before, but with no objective basis for refining the estimate, we used the 1969 data to estimate the 1973 acreages (Table 3). Our field observations indicated that most of the loss of forest acreage in the 1960's and 1970's involved flatland, mainly bottomland, and our acreage calculations reflect this fact.

As even the 1962 acreages given for the less abundant forest types — aspen and maple-beech — were likely to be inaccurate (see Essex & Gansner 1965 on acreage reliability for smaller areas), it seemed futile to attempt to update these acreages to 1973, and we used the 1962 figures. Essex & Gansner (1965) accounted for only 500 acres of pine in northern and central Illinois, perhaps reflecting a special definition they gave that forest type. As we included Christmas tree and other plantations, we could account for much more acreage from our own field work, and we have used our own estimates of pine acreage for those regions (Table 3).

The tamarack (*Larix laricina*) stands of the northeastern Illinois bogs can be considered as forest habitat, but as bogs are such unique relicts in Illinois, the presence of a bog in an impact area is an overriding consideration beyond our evaluation method.

Shrub Habitats

All Illinois shrub habitat is successional — it will eventually be succeeded by woodland — with the possible exception of small thickets of woody prairie plants. Shrub habitat occurs as a result of the abandonment of cropland ("old fields") or the clearcutting of forest or as edge (fencerows, ditches, hedges, or forest edge). Hawthorns (*Crataegus* spp.), dogwoods (*Cornus* spp.), sumacs (*Rhus* spp.), plums (*Prunus* spp.), briers (*Rubus* spp.), filbert (*Corylus americana*), and elderberry (*Sambucus canadensis*) are typical species found in shrub habitat, as well as young red cedars (*Juniperus virginiana*), sassafras, persimmon, winged elm (*Ulmus alata*), and willows in certain situations. A distinguishing characteristic of shrub habitat, as opposed to young forest, is the irregular spacing of plants often in considerable areas of grass. Both types ultimately result in forest, of course, but for a period of up to 30 years the open shrub-grass areas support certain faunal elements not found in any other habitat.

Notable among the birds in this habitat are the prairie warbler and Bachman's sparrow. We have included orchards and hedgerows in this gross habitat type because their faunal associations are similar to that of shrub habitat. Young willow clumps in open grassland or marsh areas are also included for the same reason. Where shrubs are interspersed with areas of grass and other herbaceous vegetation, we include as part of the shrub habitat the grass matrix to the outer circumference of the shrub-grown area.

The replacement time for shrub habitat is 3–25 years (Odum 1953; Bazzaz 1968), and the length of time an area remains in shrub growth is relatively short, unless disturbance is continuing, as in dunes or some pastureland.

The only estimate of shrub acreage in the state is ours for 1957–1958 (Graber & Graber 1963). Our estimate of about 500,000 acres of shrub areas in Illinois was based on the amount of shrub land we encountered in the cross-country censuses of 1957–1958 compared with the amount of row-crop acreage we encountered. The U.S. Forest Service (1968) provided acreage data for "brush and open land" (17,000 acres) on its land holdings (206,000 acres) in the Shawnee National Forest. If a similar proportion (8 percent) of potential shrub area to forest occurs outside the forest holdings, there would be about 240,000 acres of shrub habitat in the state, most of it (154,000 acres) in the southern region. The 240,000-acre figure for the state should be considered a maximum estimate, as the amount of shrub acreage outside forest holdings is probably less than that within. Nonetheless, the estimate, rough as it is, seems reasonable in relation to our 1957–1958 estimates, as we are certain that shrub acreage has declined drastically in recent decades. We have seen the destruction of this habitat in the course of our field work throughout the state. We have used this estimate because no other information on the matter exists, and for the purposes of our evaluation method even rough acreage estimates are usable.

The acreage of orchards included in this gross habitat is from the *1969 Census of Agriculture* (U.S. Department of Commerce 1972), and the edge shrub (road and railroad rights-of-way and similar areas) acreage is from observations made during our cross-country censuses.

Residential Habitats

Residential habitat includes all land occupied primarily by buildings and dwelling places of humans and their livestock and the associated vegetation. It includes inner city and suburban as well as farm residences. It offers vegetative cover varying from open grass lawns in new suburbs to modified open woodland in older areas to business districts with relatively little vegetation. The fauna is relatively poor, considering the amount and diversity of woody habitat, and is characterized particularly by three exotic pest species — rock dove, starling, and house sparrow — and three native species — common nighthawk, chimney swift, and purple martin. This habitat may not often be involved in impact areas, but we have included it for the sake of completeness, as it comprises a large and growing acreage.

Replacement time for the habitat is estimated on the basis of the age of the associated vegetation, which can usually be determined from local inquiry. If age is based on tree size, it should be remembered that growth rates are faster for trees in the open than for trees in a forest (see The Method in Practice).

Our sources for acreage of residential habitat (Table 3) were the U.S. Bureau of the Census *Area Measurement Reports* (U.S. Department of Commerce 1960) and the *1969 Census of Agriculture* (U.S. Department of Commerce 1972). Since no area data were given for towns with populations under 1,000, we extrapolated, using area data for towns with populations of 1,000–1,100 and a ratio of population to area. Rural residential habitat was estimated from the number of farmsteads, from acreage given in the *1969 Census of Agriculture*, from farmstead acreage given by Fisher (1969) for Edwards County, and from our own observations.

Marsh Habitats

Marsh is the open (unforested) area occupied by vegetation in water from about 3 feet in depth to waterlogged soil (sedge meadows), as described by Splettstaszer & Manke (1955). The bulk of marsh vegetation is made up (varying with the site) of bulrushes (*Scirpus* spp.), spike rushes (*Eleocharis* spp.), sedges (*Carex* spp. and *Cyperus* spp.), bur reeds (*Sparganium* spp.), cattails (*Typha* spp.), and certain grasses, such as manna grass (*Glyceria* spp.), common reed grass (*Phragmites communis*), cord grass (*Spartina pectinata*), rice grass (*Leersia oryzoides*), and wild rice (*Zizania aquatica*).

Succession proceeds from deeper water, as deposits of alluvial material and humus build, to shallower water to saturated soils to soils above the water table (moist meadows), and ultimately to the drier soils that support mesophytic prairie. Characteristic plants of the deeper water marsh are cattails (*Typha angustifolia*), bulrushes, coontail (*Ceratophyllum* spp.), and lotus (*Nelumbo lutea*). Cattails (*T. latifolia*) also occcur in the medium and shallower water marshes, along with bulrushes, sedges, and bur reeds. Characteristic of wet meadows are a number of species of sedges, water hemlock (*Cicuta maculata*), swamp goldenrod (*Solidago uliginosa*), and species of *Polygonum*. The drier successional associations of marsh are not sharply delineated from those of the prairie. The open water around marshes can, to a certain extent, be considered as part of the habitat. In measuring marshes, open water acreage up to the equivalent of the acreage of marsh vegetation can be included as marsh. This is the only habitat in which open water is included.

From a practical standpoint, in calculating replacement time for marshes two categories can be recognized — natural marshes and man-made marshes. A man-made marsh can be dated historically from the construction of the site. Natural marshes, such as occur most notably in northeastern Illinois, have a very long evolution reaching back to the last glaciation. Though the individual plants of marshland require much less growth time to maturity than do trees, we have given natural marshes a comparably high replacement value because of the long developmental history, manifested to some extent in the underwater soil development (Griffiths 1932; Veatch 1933). Man cannot readily duplicate the very special conditions (edaphic, climatic, geographic) that gave rise to the marshes and allowed them to be perpetuated for thousands of years; hence, such marshes may be considered irreplaceable. Man-made marshes, such as those that occur around ponds and lakes, develop fairly rapidly floristically, but usually support only a few of the characteristic marsh birds. Marsh does not readily develop to any extent around the larger reservoirs because of the extreme fluctuations in water levels of these bodies of water (Penfound 1953).

Our source of acreage data for marsh was Splettstasser & Manke (1955). We found no data from which to update their acreage figures to 1973, but their inventory omitted numerous small marshes; so even though marsh acreage is declining (Shaw & Fredine 1956), the 1955 data may still be fairly accurate. In any case they are, along with those of Shaw & Fredine (1956), the only inventory of marshes for the state. Acreage figures in these two publications are very similar and may represent the same inventory.

Grassland Habitats

Gross habitats in this category include prairie, ungrazed (fallow fields) and grazed grassland (pastures), and hayfields. Under ungrazed grassland, we have also included much (excepting shrub areas) of the acreage of road and railroad rights-of-way (598,900 acres).

Prairie, one of the climax vegetations in Illinois, now occupies a very small portion of the state, some of it in preserves, such as Goose Lake Prairie (Grundy County) and the Henry Allan Gleason Preserve (Mason County).

The bulk of prairie vegetation is grasses although in numbers of species the grasses are often equalled or exceeded by the composites. The grass species in Illinois prairies constitute less than 20 percent of the species in the habitat, but may account for up to 98 percent of the foliage area (Evers 1955). The grass associations are accompanied by a variety of other plant species, of which 63 are listed by Jones (1963) as occurring on prairie soil. Sampson (1921) recognized two major prairie successions in Illinois, for both of which the characteristic end point is big bluestem (*Andropogon furcatus*). In dry situations the successional precursor to big bluestem is little bluestem (*A. scoparius*), and in very dry situations the succession may stop with this precursor. In moist situations the successional precursor to big bluestem is switch grass (*Panicum virgatum*), which may sometimes be the hydrarch succession end point.

Other typical prairie indicators among the grasses are Indian grass (*Sorghastrum nutans*), side-oats grama (*Bouteloua curtipendula*), and porcupine grass (*Stipa spartea*) and such forbs as pasque flower (*Anemone ludoviciana*), smooth silkweed (*Asclepias sullivantii*), aster (*Aster ericoides*), wild indigo (*Baptisia leucantha*), pale coneflower (*Echinacea pallida*), rattlesnake master (*Eryngium yuccifolium*), blazing star (*Liatris spicata*), obedient plant (*Physostegia virginiana*), and compass plant (*Silphium lacinatum*) (Evers 1955; Fell & Fell 1957; Jones 1963).

Depending upon the amount of soil destruction, the replacement development of prairie may take from 10 to 30 years or longer (Table 2) through natural succession (Thomson 1940; Booth 1941; Weaver 1961). In practice, if the age of the stand cannot be determined, the higher replacement time should be used, as subtle but important physical and chemical development may occur in the older prairie just as they occur in other habitats with increasing age (Kershaw 1973).

Our data on the availability of prairie come from the Illinois literature (Evers 1955; Schramm 1970; Illinois Department of Conservation & Illinois Nature Preserves Commission 1972; Sanderson et al. 1973) and our own field data. Our acreage figure for prairie (Table 3) is probably low, as there may be numerous small areas of prairie unrecorded in the literature and unknown to us.

The prairie fauna (Table 10) now survives mainly in managed or fallow habitats that bear some resemblance to prairie in the growth form of their vegetation but are not characterized by a particular flora.

In the broad category of ungrazed and fallow habitats we include fallow agricultural fields, embracing old fields before shrub development; abandoned fields of all types with herbaceous vegetation; the successional stages to prairie; and ungrazed grass areas, much of which is along roadways and railroad rights-of-way with some on airfields. This assemblage has no distinctive flora, but the old-field succession follows a definite pattern characterized by annual weeds the first 1–2 years and progressive increases in grasses thereafter. Species of three-awned grass (*Aristida*) and broom-sedge (*Andropogon virginica*) may be present 10 years or longer. In many areas of this gross habitat the dominant stable vegetation is blue grass (*Poa pratensis*), an indicator of sustained disturbance. Blue grass is also present on many roadways, as are species of fescue grass (*Festuca*) and brome grass (*Bromus*).

This gross habitat supports elements of the prairie grassland fauna and is one of the reservoirs, along with pastures and hayfields, for what is left of the prairie fauna in Illinois. The fauna may vary with litter depth (Tester & Marshall 1961), and litter depth, in turn, with the age of the stand and amount of disturbance.

Our sources of acreage data for this gross habitat were the *1969 Census of Agriculture* (U. S. Department of Commerce 1972), Illinois Division of Highways' *Highway Mileage* (Illinois Department of Transportation 1970), *Rand McNally Handy Railroad Atlas of the United States* (1971), and our own measurements of rights-of-way for various highways, roads, and railroads. We measured airfield turf from aerial photographs in the *Illinois Airport Directory* (Illinois Department of Transportation 1973).

The pasture gross habitat is defined on the basis of land use and differs from ungrazed and fallow habitat only in the presence or recent presence of grazing livestock. The acreage excludes all woodland pasture, which is considered to be forest. Shrub areas in pasture are considered shrub habitat. The pasture habitat category is an open field habitat of grassland. The vegetation is commonly blue grass in the north and central regions and fescue (*Festuca arundinacea*) in the south, but also includes numerous other grasses and forbs. Hog pastures are among the poorest bird habitats and degenerate progressively as they are used. Most pastureland is cow pasture, which supports a varied (and different) fauna, depending upon the amount of grazing pressure.

Our source of acreage data for this gross habitat was the *1969 U. S. Census of Agriculture* (U. S. Department of Commerce 1972), and the Availability Factor is based on both rangeland and cropland used as pasture.

Hayfields are managed habitats characterized by vegetation containing large amounts of herbaceous legumes, often mixed with grasses, cultivated and cropped in the warm season for livestock forage in the cold season. This is an important habitat for the prairie fauna, but the flora is primarily cultivated exotics.

Replacement time for this habitat is relatively short, and though there is some development beyond the first year, notably in stand and duff development, in most cases duff development is likely to be poor because the fields are raked and the vegetation is removed periodically. Hayfields are often rotated with other crops after 3 years, which is about the time required for maximum development of the habitat.

Our acreage data for this gross habitat are from the *1969 Census of Agriculture* (U. S. Department of Commerce 1972), and *Illinois Agricultural Statistics* (Illinois Cooperative Crop Reporting Service 1974).

Small-Grain Fields

Small-grain fields are a monoculture habitat comprising fields of oats, wheat, barley, or rye. In aspect it resembles grassland and supports a few elements of the prairie fauna in very low population densities. Of the four crops, oat fields have the best faunal diversity, especially where fields have been heavily invaded by weeds to provide some floral diversity. These grains are annual crops, and replacement time does not exceed 1 year.

Our acreage data for this gross habitat are from *Illinois Agricultural Statistics* (Illinois Cooperative Crop Reporting Service 1974).

Row-Crop Fields

The row-crop habitat category includes primarily the monocultures of corn and soybeans and also the acreages of cotton and vegetable crops of all kinds. This is the poorest of Illinois habitats, and the associated fauna has more to do with the bare ground around the plants than with the flora. These are annual crops, and replacement time does not exceed 1 year.

Our source of acreage data for this gross habitat was *Illinois Agricultural Statistics* (Illinois Cooperative Crop Reporting Service 1974).

THE METHOD IN PRACTICE

Although we have provided certain basic data essential to the calculation of environmental indices each investigator must provide the field data that apply to his impact area. No two areas are likely to be exactly the same; however, two areas may have similar values, and by calculating the Habitat Evaluation Index and the Faunal Index, any area can be compared with any other area in Illinois with regard to ecological value. The indices are calculated from field data for the specific impact area and from factors given in this paper.

Nothing is more important at the start than a clear and precise understanding of the limits of the impact area. We recommend that the investigator work on and from aerial photographs of the area, usually available at the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service (ASCS) office in the county seat(s) of the county or counties that include the impact area. The photographs usually may not be taken out of the ASCS offices, but copies can be ordered at cost through the ASCS office. Filling the order may take up to 2 months; so if the investigator is short of time, he may work from tracings of the office copy of the photograph.

We recommend that the investigator use a photograph with a scale of 1 inch to 330 feet, or similar detail, especially for impact areas under 2,000 acres. The next common size scale (1 inch to 660 feet) is also adequate. The aerial photo, or tracing, should be taken into the field. If a tracing is used, the investigator should trace the boundaries of all habitats within the impact area. Bear in mind that the photographs are likely to be at least slightly out of date. From his field work, the investigator must verify the habitats and their boundaries and correct any acreage changes that have occurred since the photographs were taken.

Also helpful are the topographic (quadrangle) maps showing forest cover, available at cost, from the Illinois State Geological Survey, Urbana, Illinois. These maps vary greatly in preparation date, and many are too old to be of much help except for topographic features and historical data on habitat- and land-use patterns. For the greatest detail, use the 7½-minute quadrangles with forest cover (scale: 1:24,000) if available. The 15-minute quadrangles (scale: 1:62,500) are also useful. Again, bear in mind that the habitat boundaries on the maps are likely to have changed since the maps were prepared; so the investigator must verify boundaries. The combination of the most recent ASCS photograph with recent quadrangle maps makes an excellent working tool for almost any kind of field investigation. For some areas other good reference maps are available. The U. S. Army Corps of Engineers, for example, has photographs and maps of many of the major streams in the state. Also, some cities, colleges, and universities have excellent map libraries that may prove helpful to the investigator.

From the aerial photographs, maps, and, most important of all, actual measurements in the field, the next step is to determine the acreage of every gross habitat within the impact area. It is essential that all of the habitats be observed by the investigator in the field so that the habitat classification and acreage data may be accurate. Some of the acreages can be taken directly from the ASCS photographs. The ASCS staff generally will have recorded acreages of cropland. The acreages of the natural habitats can also be worked out from the aerial photographs, once they are identified and properly verified in the field and the appropriate changes have been made on the photograph or tracing. Especially where there is considerable variation in topographic relief, acreages should be checked in the field. For the purposes of the evaluation, simple pacing measurements are sufficiently accurate, providing the investigator is experienced in making such measurements.

Acreages of habitats in the impact area can be determined either directly on the photograph (Fig. 8) or on an overlay of onionskin paper by fitting the habitat areas as closely as possible into geometric figures (squares, rectangles, triangles, and circles) (Fig. 9) and calculating the areas of the figures, using standard equations. The areas may also be outlined on onionskin paper, then cut out and weighed on a sensitive balance. The weight of the paper representing the unknown area is then compared to the weight of a piece that represents a known acreage. Acreages can also be estimated by using transparent overlay grids of known acreage, fitting the grids over the habitat areas on the photograph, and recording the acreages as the grid is moved across the photograph. This method may be somewhat less accurate, but it is faster than other methods and may be more practicable for very large impact areas. The acreages of a linear habitat, even a crooked one, can be calculated from its length on the photograph and a figure for average width based on measurements in the field at three or more places along the length of the habitat.

While in the field checking the identities and acreages of the different habitats in the impact area, the investigator can also be determining the ages of the different habitats. Cropland, for the most part, can be considered to have an age of 1 year regardless of its stage of development or harvest, and so the investigator should concentrate his efforts on the natural habitats. Local inquiry can be helpful here, as many farmers, for example, know the histories of tracts of land in their neighborhoods. Perhaps the most difficult habitat to age, because of its long life, is forest. If the history of the tract is not known, the age can be estimated at least roughly on the basis of tree size (Table 13). We are fully aware of the large variability in growth rates of trees on different sites (Carmean 1971). Nonetheless, there is correlation between age and tree size, regardless of site, and for the purposes of our evaluation method this procedure is adequate. Generally, there is no other reliable source of data on ages of forest tracts. We do not recommend core drilling, as it damages trees, and ring counts are little better than diameter measurements for the purpose of ageing trees (Glock 1941 and 1955; Studhalter 1955). Drilling is also time-consuming. The growth rates in Table 13 are based on average sites, where site data were provided, and on areas in Illinois or as close to Illinois as we could find.

To determine the age of a stand of trees, if the history is unknown, the investigator should measure a sample of dominant (larger) trees in each tract of notably different age or composition. The sampling method is not critical. We suggest measuring about one tree per acre or fewer in large tracts (50 acres or more). Run a transect through the tract on its longest axis or on the diagonal in a squarish tract. Measure oaks, preferably, because they are almost always present and better growth data are available for oaks than for other species (Table 13). Otherwise, use any of the other species listed in Table 13. In walking the transect, which need not be a straight line, measure the largest tree seen every 50–100 feet or so. This technique is not intended to be an exhaustive search for the largest trees. All that is necessary is that some of the larger trees encountered be measured. Measure the diameter of the trunk about 4–4.5 feet above ground (DBH). If available, use calipers or diameter tapes to make the measurements. An ordinary measuring tape can be used, but care must be taken, especially with big trees, to

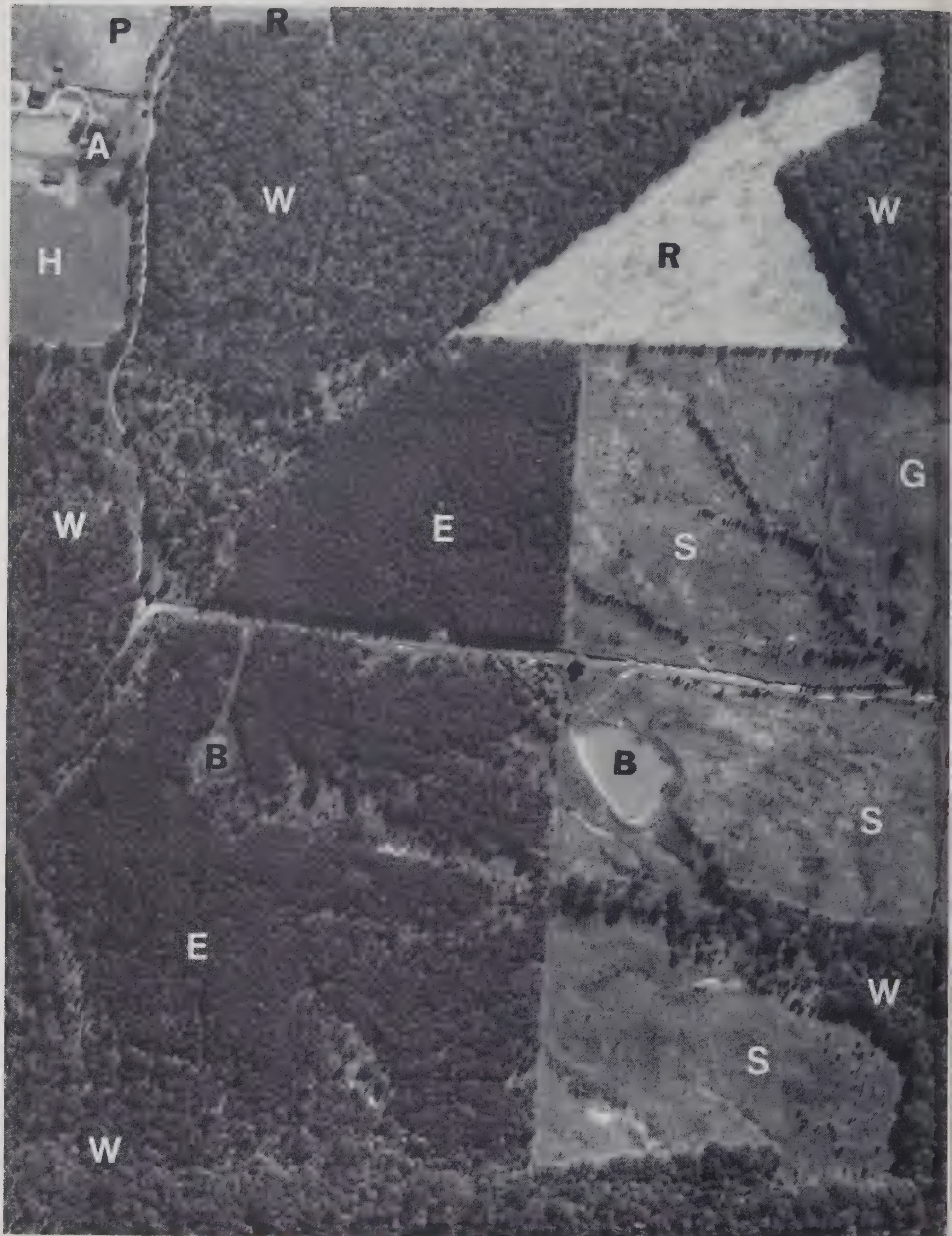

Fig. 8. — Aerial photograph showing a portion of the experimental impact area used to test the method presented in this paper. The scale of the photo is 330 feet per inch, or 2 square inches equals 10 acres. Note that pines (E) are distinguishable from deciduous hardwoods (W). Bare field (R), ponds (B), residential area (A), and shrub habitat (S) are easily identified. Ungrazed grass (G), hayfield (H), and pasture (P) are difficult to distinguish in aerial photos and must be identified by examination in the field.

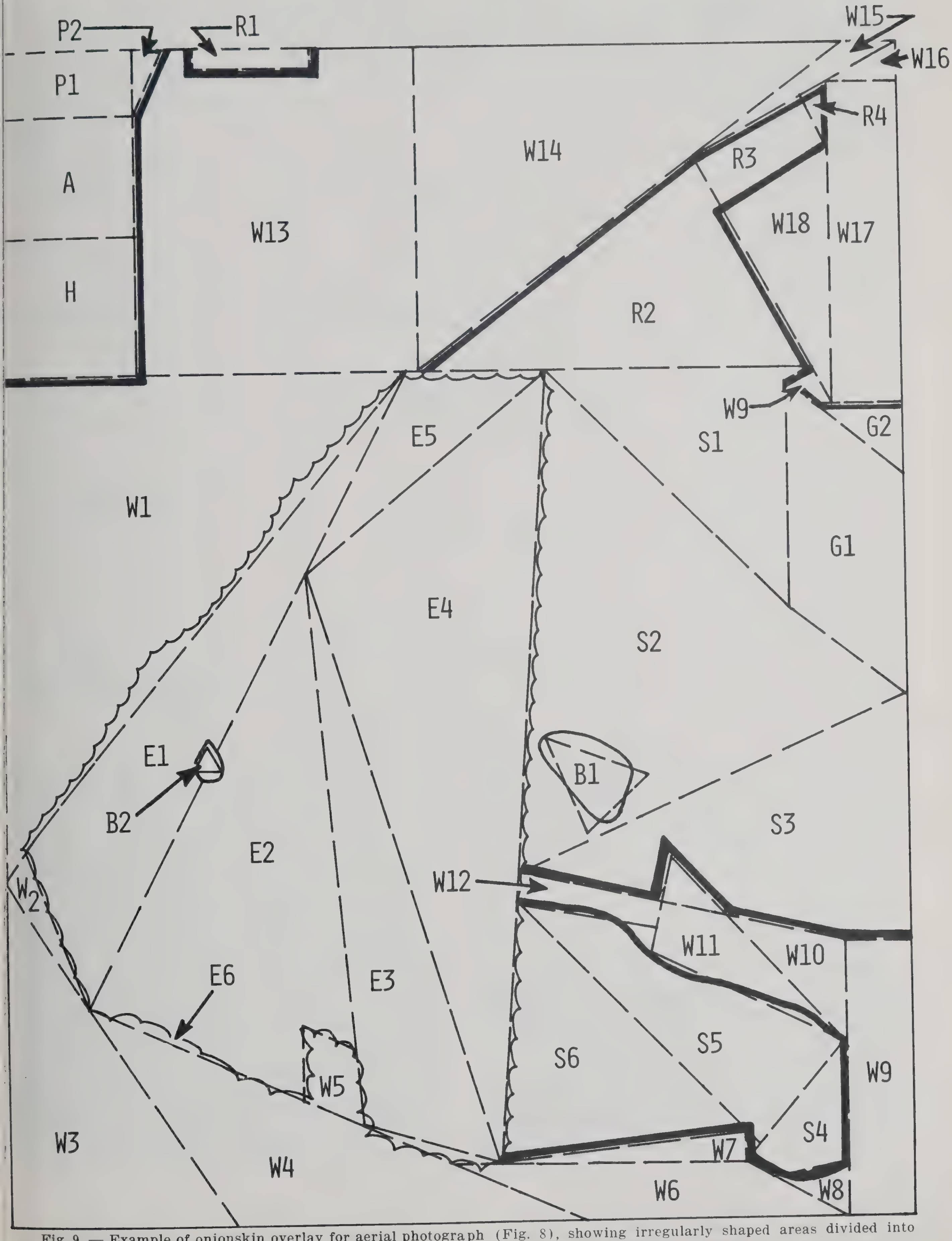

Fig. 9. — Example of onionskin overlay for aerial photograph (Fig. 8), showing irregularly shaped areas divided into geometric figures for acreage measurements (based on the scale of the photo) of different habitats.

TABLE 13. — Growth rates of representative tree species. This table is to be used to determine approximate ages of tre and replacement times for forests.

Species	Annual Growth Rate[a]	Comment on Use of Growth Rate	Reference and Locality of Reference Data
Ash, green and white *Fraxinus pennsylvanica* and *F. americana*	0.22		Lorenz (1962) Central Illinois
Basswood *Tilia americana*	0.22		Chittenden & Robbins (1930) Southern Michigan
Beech, American *Fagus grandifolia*	0.12		Chittenden & Robbins (1930)
Box-elder *Acer negundo*	0.24		Lorenz (1962)
Cherry, black *Prunus serotina*	0.27		Conard (1918) Central Iowa
Cottonwood *Populus deltoides*	0.60 0.56 0.53	Use this rate for 4–15″ DBH Use this rate for 16–25″ DBH Use this rate for over 25″ DBH	Williamson (1913) Mississippi Valley Gilmore et al. (1973*a*) Southern Illinois
Cypress, bald *Taxodium distichum*	0.20 0.13	Use this rate for 4–40″ DBH Use this rate for over 40″ DBH	Mattoon (1915*b*) Maryland, Louisiana
Elm, American *Ulmus americana*	0.31 0.25 0.19	Use this rate for 4–10″ DBH Use this rate for 10–15″ DBH Use this rate for over 15″ DBH	Lorenz (1962) Chittenden & Robbins (1930)
Elm, red *U. rubra*	0.49		Conard (1918)
Gum, sweet *Liquidambar styraciflua*	0.30		Gilmore et al. (1973*b*) Southern Illinois
Hickory, shagbark *Carya ovata*	0.22		Conard (1918)
Maple, silver *Acer saccharinum*	0.45		Lorenz (1962) Conard (1918)
Maple, sugar *A. saccharum*	0.15 0.10	Use this rate for 4–14″ DBH Use this rate for over 14″ DBH	Chittenden & Robbins (1930)
Oak, black *Quercus velutina*	0.24 0.15 0.10	Use this rate for 4–10″ DBH Use this rate for 11–15″ DBH Use this rate for over 15″ DBH	Vestal (unpublished) Southern Illinois Gevorkiantz & Scholz (1944) Southwestern Wisconsin
Oak, bur *Q. macrocarpa*	0.26 0.16 0.11	Use this rate for 4–10″ DBH Use this rate for 11–15″ DBH Use this rate for over 15″ DBH	Lorenz (1962) Conard (1918)

get an accurate measurement. If slopes are involved, trees should be measured on different faces (north-facing, south-facing slope) and at upper and lower levels of the slopes. If there is a definite floodplain, look for a change in species composition to elm-ash, as this is treated as a different gross habitat.

The field work is best done by two persons, one used primarily as a recorder of data. We have found it convenient to designate each tract of habitat with a code letter directly on the photograph of the impact area or the overlay tracing and then to record the field data by using the code letters. Record the tract and the species and size of each tree measured.

After the measurements have been made for each tract, age the trees on the basis of the growth rates given in Table 13 $\left(\text{age} = \frac{\text{diameter of tree}}{\text{growth rate of species}}\right)$. Finally, select the 10 oldest trees of each 20 measured, and use the average age of these oldest trees as the age of the stand. Do not be concerned if the tree ages are not uniform. In virtually every stand are some older trees spared in earlier cuttings, and your sample will include some of these — roughly proportional to their numbers — as well as younger trees.

Once the habitats and their acreages and ages are known, the Habitat Evaluation Index (HEI) can be calculated as a first step (Table 14). To compute the HEI, consider each area of each gross habitat with a different age as a distinct unit. Different areas of the same gross habitat can be considered as a unit (summed) if they are of the same or nearly the same age. For example, in the case of forest we sum the acreage of tracts within 20-year age classes (90 to 110 years = 100-year class). Prepare a tabulating sheet like Table 14. Enter each area of each gross habitat of a different age as shown, with the habitat name first, next its acreage, then the Re-

TABLE 13. — Continued

Species	Annual Growth Rate[a]	Comment on Use of Growth Rate	Reference and Locality of Reference Data
k, pin *Q. palustris*	0.34		Vestal (unpublished) Southern Illinois
k, post *Q. stellata*	0.17		Vestal (unpublished) Southern Illinois
k, red *Q. rubra*	0.152		Robbins (1921) Missouri
ks *Quercus* spp.	0.16 0.128 0.104	Use this rate for 4–12″ DBH Use this rate for 13–18″ DBH Use this rate for over 18″ DBH	Gevorkiantz & Scholz (1944)
ne, loblolly *Pinus taeda*	0.30 0.25 0.20	Use this rate for 4–10″ DBH Use this rate for 11–15″ DBH Use this rate for over 15″ DBH	Forbes & Demmon (1929) Virginia, Florida, Texas Arnold (1973) Southern Illinois
ne, shortleaf *P. echinata*	0.29 0.25 0.20 0.15 0.10	Use this rate for 4–8″ DBH Use this rate for 9–12″ DBH Use this rate for 13–17″ DBH Use this rate for 18–20″ DBH Use this rate for over 20″ DBH	Mattoon (1915*a*) Western Arkansas Arnold (1973) Forbes & Demmon (1929)
ine, white *P. strobus*	0.23 0.12	Use this rate for 4–15″ DBH Use this rate for over 15″ DBH	Lorenz (1962) Dwight (1926) Ontario, Canada
assafras *Sassafras albidum*	0.27		Rennels (1971) Central Illinois
ycamore *Platanus occidentalis*	0.44		Vestal (unpublished) Gilmore (1973) Southern Illinois
alnut, black *Juglans nigra*	0.43 0.30	Use this rate for 4–15″ DBH Use this rate for over 15″ DBH	Conard (1918) Losche (1973) Southern Illinois Lorenz (1962) Smith (1973) Central Missouri
illow, black *Salix nigra*	0.54 0.46 0.28	Use this rate for 4–20″ DBH Use this rate for 21–26″ DBH Use this rate for over 26″ DBH	Lamb (1915) Arkansas

[a] Given in inches. This figure divided into the diameter (in inches) of a tree will give the approximate age of the tree in years.

lacement Factor for the habitat area. In the fourth olumn enter the Final Availability Factor for the abitat and region from Table 5. Note that the Avail- bility Factors given in Table 5 already have the hanging Availability Factors incorporated.

With these tabulations made, the computations can e started. For each habitat area of different age, ultiply the Replacement Factor (age) by the Avail- bility Factor and record the product (Replacement- vailability Product) in the fifth column. The next tep in the computation is to calculate the ratio of each abitat-age group to the total acreage in the impact rea (ratio $= \frac{\text{acreage of habitat-age group}}{\text{total acreage of impact area}}$). Thus, n our example (Table 14) the ratio for the first age roup of bottomland forest habitat $= \frac{6.9 \text{ acres}}{643.9 \text{ acres}} =$ .0107. Record this ratio after the appropriate category in column six. After all ratios are recorded, multiply the Replacement-Availability Product of each habitat-age group (column five) by the ratio of total acreage in the impact area (column six) and enter the resulting product in column seven. We call this product the Habitat Factor for each habitat-age group, and the sum of all the products (column seven) we call the Habitat Factor for the impact area.

Although we have said nothing about biological richness *per se*, the Habitat Factor is an indicator of biological richness, because the richest habitats tend to have the highest Habitat Factor values. After the Habitat Factor for the impact area has been calculated, a final procedure is required to standardize the evaluation. The standardization is obtained by comparing the Habitat Factor for the impact area with the Regional Average Habitat Factor (Table 15) for the region that contains the impact area. If the impact area crosses regional boundaries, the Habitat Factor of the impact area can be compared to the Regional Average Habitat Factor of the region that includes *most* of the impact area. Preferably, however,

TABLE 14. — Example showing the tabulation of data for the calculation of the Habitat Factors and Habitat Evaluatio Index on a sample impact area in southern Illinois. The Habitat Availability Factors used were for the southern regio (Table 5).

Gross Habitat	Acres of Habitat in Impact Area	Replacement Factor	Final Availability Factor	Replacement Availability Product	Part of Impact Area Acreage	Habitat Factor
Bottomland forest	6.9	146	132	19,272	0.0107	206.21
Bottomland forest	26.3	97	45	4,365	0.0408	178.09
Upland oak-hickory	88.8	100[a]	20	2,000	0.1379	275.80
Upland oak-hickory	55.7	120	28	3,360	0.0865	290.64
Upland oak-hickory	4.9	146	28	4,088	0.0076	31.06
Upland oak-hickory	26.2	175	28	4,900	0.0406	198.94
Upland oak-hickory	45.8	200	28	5,600	0.0711	398.16
Pines	61.6	25	18	450	0.0956	43.02
Shrub	78.0	17	19	323	0.1212	39.15
Residential	1.1	20	0.1	2	0.0017	0.003
Residential	3.3	157	0.1	16	0.0052	0.08
Ungrazed grass	35.5	10	21	210	0.0551	11.57
Pasture	141.2	10	31	310	0.2192	67.95
Hayfields	44.1	3	52	156	0.0685	10.69
Small grain	7.1	1	51	51	0.0111	0.57
Row crop	17.4	1	0.1	0.1	0.0270	0.003
Total	*643.9*				*0.9998*	*1,751.94*

Regional Average Habitat Factor (for southern region) = 397.46

Habitat Evaluation Index (HEI) for impact area $= \dfrac{1{,}751.94}{397.46} = 4.41$

Average Habitat Factor for state = 267.97

HEI (state) for impact area $= \dfrac{1{,}751.94}{267.97} = 6.54$

[a] Indicates age class between 90 and 110 years. The 120- and 200-year classes were similarly treated.

the impact area will be considered as two units divided along regional boundaries (Fig. 2), and the data for each unit will be considered separately.

The Regional Average Habitat Factors (Table 15) were calculated in the same way that the Habitat Factors for the impact area were calculated, except that average, or in several cases median, values were used for the Average Replacement and Availability Factors. The Regional Factor is thus not strictly an average, but it is the closest approximation we could make of an average or median value for each habitat, based on the references given under the habitat discussions and in Table 2. Ideally, the Regional Average Habitat Factor would be a true average, but the present knowledge of habitats is inadequate for such an attainment, and our best estimate is adequate as a value for comparison. The habitat with which we had the most difficulty in determining an Average Regional Factor was marsh, because of the great disparity in replacement age between natural and man-made marshes. The best estimate we could make of the average replacement time for this habitat was based on the acreage ratio between natural and artificial ponds and lakes (in which the marshes develop) in the three regions of the state from data presented by Lopinot (1973). Also difficult was the calculation of the average age of residential habitat, which we finally based on the growth of the human population in the three re gions of the state.

The Regional Average Habitat Factor (RHF varies from region to region, the south being th richest in habitats by far, as is clearly reflected i the factor (RHF = 397.46 in the south, 231.80 fo the north, and 208.38 for the central region). Th Average Habitat Factor for the state (267.97) i the average for the regional factors multiplied b their respective regional acreages and divided b the state acreage.

The final step in standardizing the Habitat Facto for the impact area is to divide the Regional Averag Habitat Factor into the Habitat Factor for the impact area. The quotient from this division we cal the Habitat Evaluation Index, or HEI (HEI = $\dfrac{\text{Habitat Factor for the impact area}}{\text{Regional Average Habitat Factor}}$). The HEI is a index to the wealth of habitats on the impact area An HEI of 1.0 indicates that the area is average fo the region, while an HEI of 4.4, as in our exampl (Table 14), means that the area is 4.4 times abov the average for the region. An HEI of 0.5 means tha the impact area is only half as rich in habitats as i the region. By this method every area in the stat can be compared with every other area in term of habitat richness on a standardized base. To com-

TABLE 15. — Regional Average Habitat Factors for gross habitats in three regions of Illinois.

Gross Habitat	North				Central				South			
	Average Replacement Factor	Average Availability Factor	Part of Total Acreage	Regional Average Habitat Factor	Average Replacement Factor	Average Availability Factor	Part of Total Acreage	Regional Average Habitat Factor	Average Replacement Factor	Average Availability Factor	Part of Total Acreage	Regional Average Habitat Factor
Oak-gum-cypress	...	...	...	...	...	...	...	...	101.0	557.0	0.001338	75.27
Elm-ash-cottonwood	45.6	106.8	0.007910	38.52	45.5	74.1	0.015032	50.68	45.5	42.4	0.056063	108.16
Oak-hickory	54.2	61.9	0.019563	65.63	54.2	37.5	0.038423	78.09	54.2	20.1	0.134928	146.99
Maple-beech	49.3	840.7	0.000256	10.61	49.1	577.9	0.000374	10.61	49.1	307.1	0.000722	10.89
Aspen	34.0	171.0	0.000780	4.53	34.0	549.0	0.000194	3.62	...	...	...	...
Pine	21.6	481.1	0.000414	4.30	21.6	277.3	0.000710	4.25	21.6	31.8	0.005072	3.48
Shrub	15.0	66.0	0.004346	4.30	15.0	42.0	0.006452	4.06	15.0	19.0	0.019552	5.57
Residential	60.0	0.1	0.116833	0.70	60.0	0.1	0.035038	0.21	60.0	0.1	0.032218	0.19
Marsh	385.5	48.0	0.003863	71.48	233.1	116.0	0.001076	29.09	108.2	303.0	0.000365	11.97
Prairie	20.0	163.0	0.000652	2.13	20.0	928.0	0.000109	2.02	20.0	687.0	0.000152	2.09
Ungrazed and fallow	5.0	20.0	0.072739	7.27	5.0	21.0	0.045303	4.76	5.0	21.0	0.046316	4.86
Pasture	5.0	31.0	0.091464	14.18	5.0	31.0	0.100886	15.64	5.0	31.0	0.118415	18.35
Hayfields	2.0	52.0	0.055056	5.73	2.0	53.0	0.029219	3.10	2.0	52.0	0.041291	4.29
Small grain	1.0	52.0	0.045325	2.36	1.0	52.0	0.041978	2.18	1.0	51.0	0.104070	5.31
Row crop	1.0	0.1	0.580797	0.06	1.0	0.1	0.685205	0.07	1.0	0.1	0.439495	0.04
Total			*0.999998*[a]	*231.80*			*0.999999*[a]	*208.38*			*0.999997*[a]	*397.46*

State Average Habitat Factor = 267.97

[a] A discrepancy exists in these sums, as the original calculations were made with seven-place figures, reduced here because of space limitations.

pare areas between regions, use the state Average Habitat Factor as the divisor instead of the Regional Factors for each impact area. Any area with an HEI above 1.0 must be given careful consideration for preservation, and the higher the value reaches above 1.0, the greater the concern should be for the preservation of the area. The highest HEI we have found for any area in Illinois is 386, calculated for the oldest forest stand on the island of the Horseshoe Lake Nature Preserve in Alexander County. Few areas will even approach such a high index.

The Habitat Evaluation Index is the first of two indices used in the evaluation of an impact area. The HEI tells us something of the potential value of the habitats in an area but nothing about the actual biological value of the habitats. This is the function of the second index, the Faunal (Floral) Index. This index adds greatly to the evaluation, but requires considerably more study and perhaps the help of a specialist in the field, depending upon the background of the investigator. Only rarely will the biological data have been collected and even more rarely will it have been published for the specific impact area in question. Considering birds, for example, recent breeding population data are available on less than 2,000 acres of Illinois land, making the probability about 1 in 18,000 that data will be available for a specific area, and the data for this index should be current. Floral studies are probably just as scarce. Therefore, the investigator will probably save time by assuming that the biological data on his impact area have not been collected. If the investigator has had sufficient training, he can acquire the data by himself. If not, he may be able to get help from one or more of the biologists in the state — in colleges and universities or other state agencies.

The goal of the bird studies is to acquire a good estimate of the number of breeding species of each gross habitat in the impact area. This work is best done in June and July to eliminate migrant species as much as possible, but it can start as early as March or April to get the early nesters, such as the hawks and owls. Ideally, the investigator might survey on foot all of the gross habitats in the impact area at least once a month from March through July, listing the potential nesting species for each habitat. This aspect of the study can begin when the first habitat measurements are made for the HEI determination. If the investigator is short of time, however, the bird data can be collected in June and July. The survey should include several night trips to detect nocturnal species. This survey for bird species need not be a quantitative census for the purposes of the impact-area evaluation. The investigator should look for evidence of nesting for all species, but absolute proof of breeding is not essential. The presence of territorial birds in the habitats of the impact area will usually be indicative of breeding. The most common source of error stems from the fact that birds often forage in habitats other than the nesting habitat. Even a very experienced investigator should cover the impact area at least twice for the bird surveys.

A problem that arises in evaluating a fauna with a number system is that the number of species to be found in a given habitat is finite, so that as the habitat area increases beyond a certain size, increased coverage does not result in the finding of an increased number of species. To circumvent this problem, it is necessary to divide large impact areas into faunal units, each of which, for the purpose of the faunal evaluation, is treated as a separate impact area. This problem does not arise in the case of the Habitat Evaluation Index, only in calculating the Faunal Indices. We suggest that each 500 acres of a given habitat be treated as a separate unit in the faunal evaluation. Thus, after the investigator has developed sufficient familiarity with the impact area and knows the tracts and acreages of each gross habitat, he must divide those habitat areas that exceed 500 acres into geographic faunal units of about 500 acres each and then collect and segregate the bird data within each unit. The drawing of the unit lines is not critical. If the total acreage of, say, bottomland forest on the impact area were 520 acres, there would be little point in splitting the extra 20 acres off as a separate unit. If, on the other hand, the bottomland forest area were 600 acres or more, then the faunal data for the area in excess of 500 acres should be considered separately.

The calculation of the Faunal Index differs in yet another major way from that of the Habitat Evaluation Index, as the Faunal Index does not take into account row-crop and small-grain acreage. This difference occurs because the Faunal Index has a different function than the HEI. While the HEI refers to the overall habitat composition of the impact area, the Faunal Index refers to the *quality* of the habitats in the impact area. Row-crop and small-grain habitats are essentially *without* quality as natural habitats, and they support no faunal specialties (species nesting in only one gross habitat) (Table 11); therefore, it is pointless to include these habitats in the calculation of the Faunal Index.

After all the faunal data have been collected on all habitats in the impact area (excluding row-crop and small-grain acreage), the point evaluations can be made (Table 16). List the breeding species found for each gross habitat, bearing in mind that for a gross habitat including more than 500 acres the data should be segregated by 500-acre units. After you have completed the bird list(s) for a given habitat, turn to the appropriate table for that habitat (e.g., Table 6 for forest, Table 7 for shrub habitat) and put the point value for each species after the species name. Note that in Tables 6–11 we have recorded

TABLE 16. — Example showing the tabulation of data for the calculation of the Faunal Indices for habitats on a sample impact area (see Table 14).

Habitat	Acres	Number of Species	Total Species Points	Expected Species Points	Point Difference	Average Species Index	Expected Average Index	Point Difference	Common Log of Acreage	Faunal Index	Expected Faunal Index
Bottomland forest	33.2	25	520	310	+210	20.8	12.4	+8.4	1.52114	342	237
Upland forest	221.4	38	680	540	+140	17.9	14.2	+3.7	2.34518	290	256
Pines	61.6	8	300	90	+210	37.5	11.2	+26.3	1.78958	168	190
Shrub	78.0	25	790	380	+410	31.6	15.2	+16.4	1.89209	418	217
Residential	4.4	15	180	210	−30	12.0	14.0	−2.0	1.30103[a]	138	42
Ungrazed grass	35.5	4	120	70	+50	30.0	17.5	+12.5	1.55023	77	113
Pasture	141.2	3	40	50	−10	13.3	16.7	−3.4	2.14983	19	139
Hayfields	44.1	5	80	90	−10	16.0	18.0	−2.0	1.64444	49	120

[a] The smallest divisor used in calculating the Faunal Index is the log of 20 acres (1.30103) even when the acreage is less. Distortion increases greatly below that acreage.

the special (doubled base) value for the habitat specialties (e.g., red-shouldered hawk — a bottomland forest specialty). The special value is applied to a species even when, as occasionally happens, it is found nesting in a habitat other than its primary, special one. Such occasional occurrences do not change the fact that the species is still *primarily* dependent for survival upon one habitat.

After all the assigned values have been recorded for the breeding species of the habitat under consideration, they are next summed. From this sum two faunal indices are derived. The first is the Average Species Index, calculated simply by dividing the number of species into the sum of points. The second is the Faunal Index for the habitat, calculated by dividing the sum of the species values by the common logarithm of the number of acres of a particular habitat on the impact area (Table 16). Note that in cases of small-acreage habitats, particularly under 20 acres, the Faunal Index becomes distorted, increasing out of proportion as the acreage declines. Therefore, in practice, we never use a divider lower than the log of 20 acres (1.30103) no matter how low the acreage goes.

To see the meaning of the Total Species Points and the Average Species Index, turn to Fig. 10–15. These figures, each for a different major habitat type, present a graph line showing the relationship between species variety and species abundance (plus habitat specialization) and the size of the area surveyed through the simple numerical code we have derived. The point evaluation system of the faunal indices is based on the elementary observation that in a census of any habitat the most common species are likely to be encountered first, the rarer species later. Thus, in a point system such as ours, based in part on population levels, the average point value per species will increase as the number of species or the acreage censused, or both, increase. The richer the habitat is in both common and rare species, the higher will be the Average Species Index value. Also, as the ratio of rare to common species increases and as the ratio of habitat specialties to non-specials increases, so will the Average Species Index increase. Counterbalancing the increasing point value of the species as more acreage is censused is the decline in number of additional species found. For a given acreage of habitat both the Total Species Points and Average Species Index reflect the quality of the habitat. A tract that supports only a few of the most common and presumably most tolerant species is, biologically, less valuable than a tract that supports a large variety of both common and rare species.

Fig. 10–15 were derived from our statewide censuses. Not only was this the only set of Illinois data from which to judge different Illinois habitats in relationship to their bird populations, it was data reasonably well suited as a basis upon which to make comparisons, because the censuses represent a cross section of Illinois bird populations and their habitats. Because the habitats were censused as they were encountered on a series of straight-line transects and not selected in advance for richness or any other quality, the bird-habitat data are probably reasonably representative of Illinois habitats in general. The greatest shortcomings of the censuses are that they represent only 2 years and only about 1 acre in 5,000 of Illinois land. The data are, however, much more complete than those available for most states.

In interpreting the indices, it is best to consider each major habitat separately although a single index for the impact area can be calculated, as will be explained. The main reason for considering the habitats separately relates to the varying situations that may be encountered on any sizeable tract of land. Not all habitats in an area will be equally rich faunistically — just because the forest habitat on an area is rich does not mean that the grassland habitats on the area will be rich also. In determining the fate of a tract of habitats, we are most concerned about the fate of the richest areas, because they and not the average habitats in the impact area determine its value. It is the responsibility of the impact investigator to find and evaluate those areas of habitats on the impact area that are particularly deserving of special consideration.

In considering the different habitats on an impact area, the investigator should be aware of a truism about Illinois habitats that affects the interpretation of the data. In Illinois, grassland and marshland habitats become biologically richer as one goes north, whereas forest habitats increase in richness as one goes south. The contrast is most radical at the geographic extremes in both cases.

Considering each habitat separately and with the appropriate habitat graph in hand (e.g., Fig. 10 for bottomland forest), first follow the line that represents the number of nesting species in your sample of habitat from the top scale down to the habitat-fauna curve line. At the coordinate of the species-number line and the habitat-fauna curve line, lay a straightedge horizontally across the page parallel to the top scale and read the Expected Total Species Points on the left scale and the Expected Average Species Index on the right scale. If the index values on the graph are higher than the values obtained for the habitat in the impact area, then the habitat is not exceptional or perhaps is even poor in quality (depending upon the difference in the two readings). If the values for the habitat in the impact area are well above the expected values on the graph, then the habitat can be considered superior in faunal quality and must be given extra consideration in the final plans for the impact area. Note that all grassland habitats (grazed, ungrazed and fallow, prairie, and hayfields) are evalu-

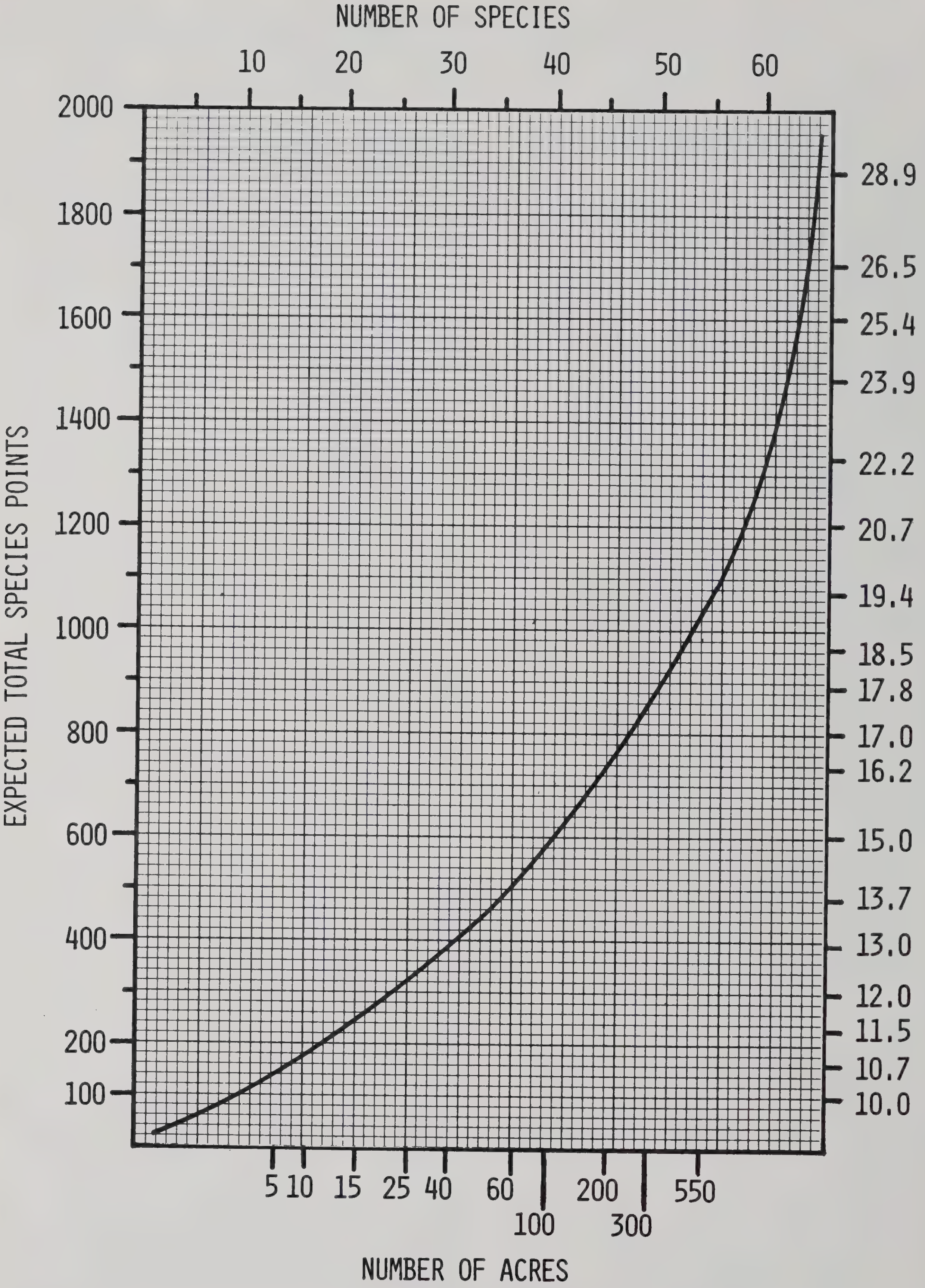

Fig. 10. — Relationship of numbers of species and their assigned index values (based on population levels and habitat specialization) to acreage censused in bottomland forest habitat in Illinois. The graph line is used to interpret calculated Faunal Indices in evaluating impact areas. See text for explanation.

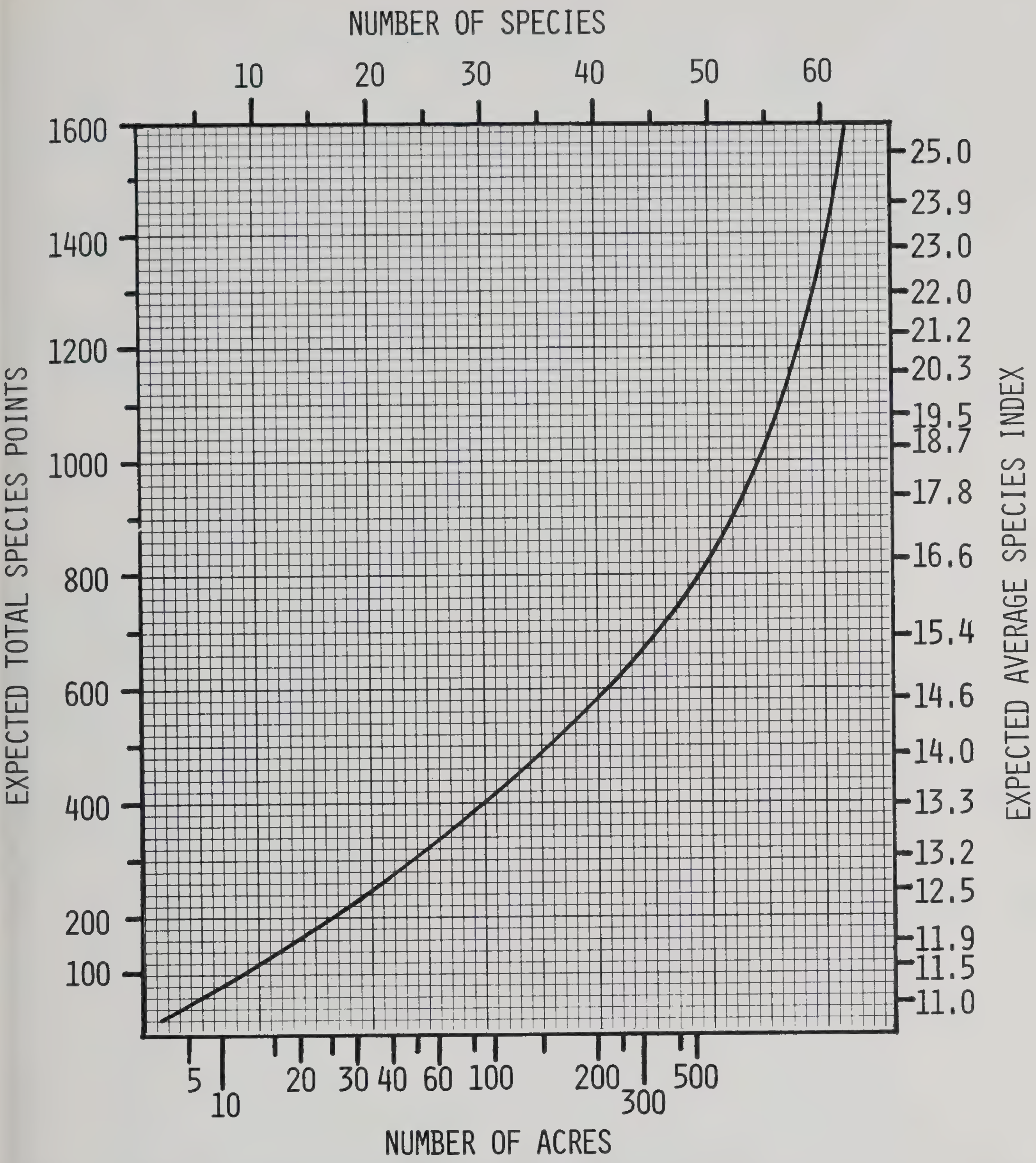

Fig. 11. — Relationship of numbers of species and their assigned index values (based on population levels and habitat specialization) to acreage censused in upland forest habitat in Illinois. The graph line is used to interpret calculated Faunal Indices in evaluating impact areas. See text for explanation.

ated on Fig. 15; all bottomland forest, including gum-cypress, is evaluated on Fig. 10; and all other forest, including pine, is evaluated on Fig. 11. Note also that, though it is easy to read the graphs, care must be taken to read them precisely. Slight discrepancies in the readings are, however, not a significant source of error in the final calculation of the indexes.

The values of the Expected Total Species Points and Expected Average Species Index (Table 16) will not always indicate the same evaluation and should not necessarily do so, as they are measurements of different characteristics. The Total Species Point value may be high either because the habitat has many species or because it has a high proportion of uncom-

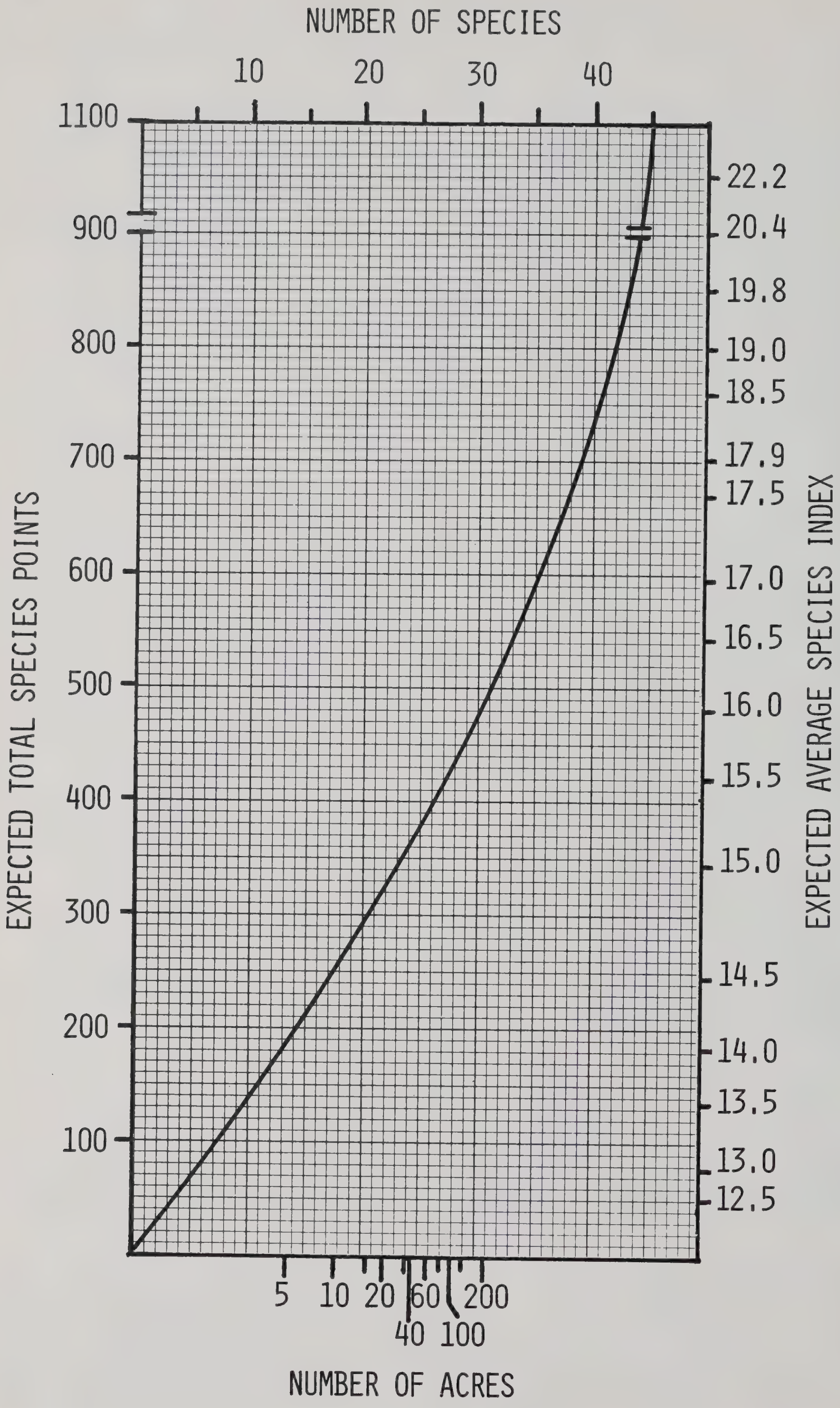

Fig. 12. — Rel tionship of number of species and thei assigned index value (based on populatio levels and habita specialization) t acreage censused i shrub habitat in Ill nois. The graph lin is used to interpre calculated Faunal In dices in evaluatin impact areas. Se text for explanation

non species and/or habitat specialties. The latter s, of course, indicated by a high Average Species Index.

The Faunal Index is perhaps the best single indicator of habitat quality. It takes into account the acreage of the habitat and the Total Species Points without direct reference to the number of species. The Faunal Index is interpreted from the same graph as is the Average Species Index, but in the case of the Faunal Index, the interpretation is made from the acreage scale at the bottom of the graph rather than the number-of-species scale. Turn to the appropriate graph for the habitat under consideration (e.g., Fig. 10 for bottomland forest). From the bottom axis (number of acres) follow the indicator line that most closely represents the acreage of your sample of habitat (here you may have to extrapolate between acreage points, but a good approximation is adequate) upward until it intersects the habitat-fauna curve. At the coordinate of the acreage-indicator line and the habitat-fauna curve, follow the abscissa line to the left-hand scale and read another value for Total Species Points. This is the Expected Total Species Points for that acreage. Into that value divide the common logarithm of the acreage of your habitat sample, as was done to calculate the Faunal Index for your habitat sample. This division gives the Expected Faunal Index. If the Faunal Index of your impact area is well above the Expected Index, it indicates that *that* habitat on your area is of superior quality.

If a single index figure is desired for the entire

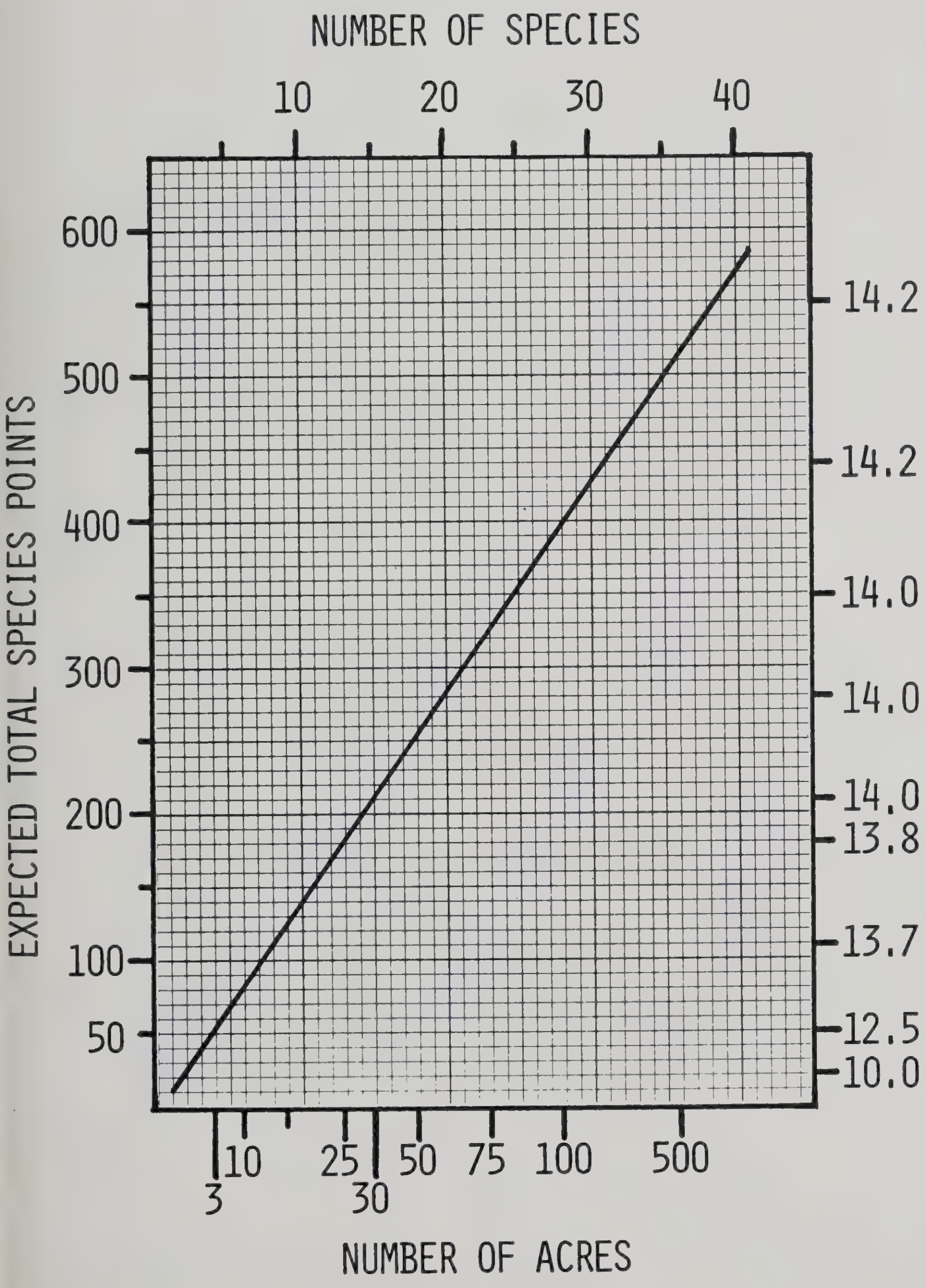

Fig. 13. — Relationship of numbers of species and their assigned index values (based on population levels and habitat specialization) to acreage censused in residential habitat in Illinois. The graph line is used to interpret calculated Faunal Indices in evaluating impact areas. See text for explanation.

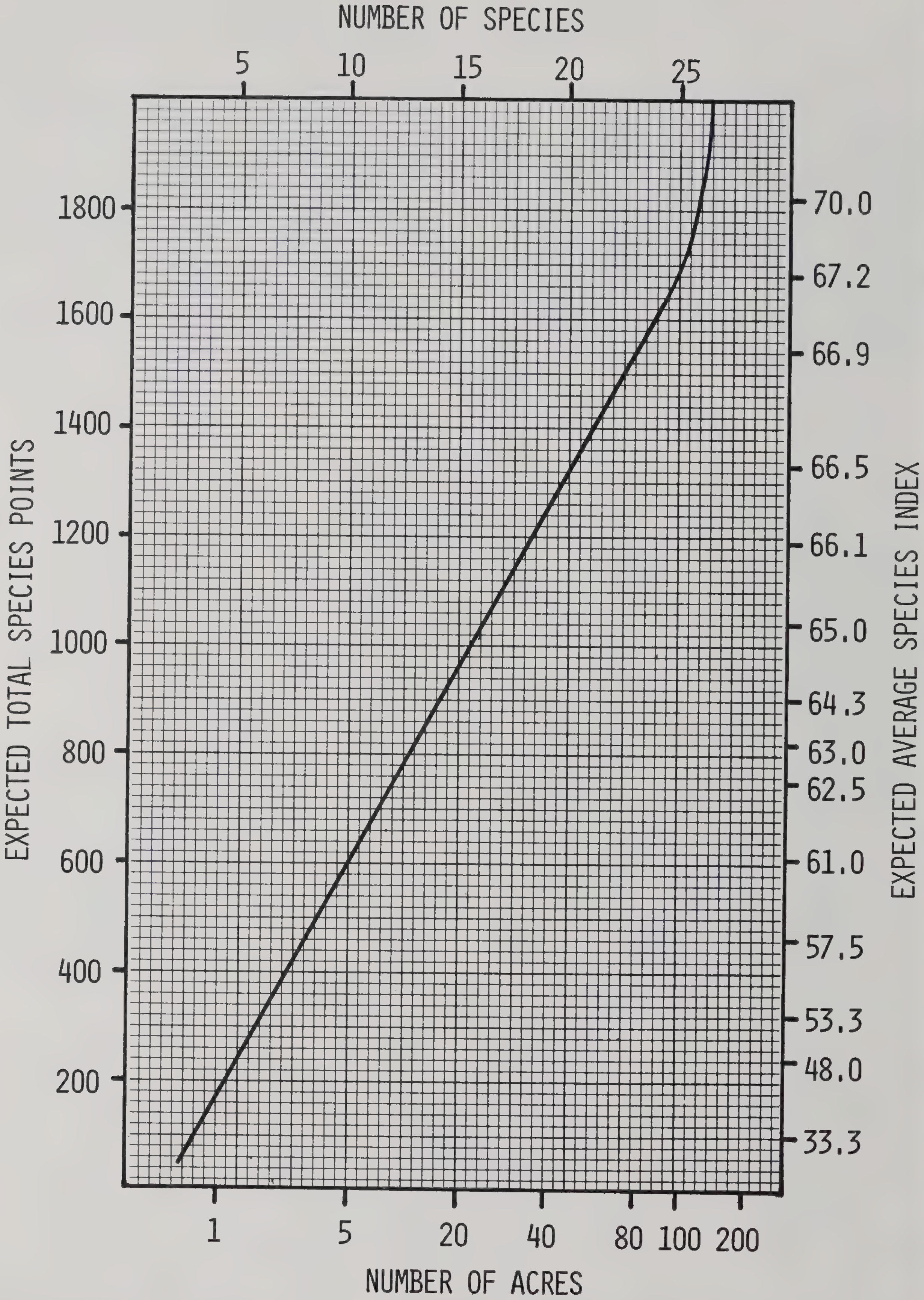

Fig. 14. — Relationship of numbers of species and their assigned index values (based on population levels and habita specialization) to acreage censused in marsh habitat in Illinois. The graph line is used to interpret calculated Faunal Ir dices in evaluating impact areas. See text for explanation.

npact area (note the cautionary comments above), ne investigator can sum the individual habitat indices. 'abulated Faunal Index values (Table 16) above ne habitat-fauna graph line can be counted as posi- .ve (+) points, and Faunal Index values that fall elow the graph line as negative (—) points. The um of indices for all tested habitats in the impact rea is then an index for the entire area, and a ositive final value indicates high average quality of abitats in the impact area.

It should be obvious that the indices, if based n thorough, accurate field work, are indicative only f the present condition of the habitats, not of their uture potential. To some extent the Habitat Evalu- tion Index takes future potential, or at least future availability, into account, and in the final evaluation the Faunal Indices for an impact area should be considered in combination with the HEI for the area.

In setting up our method of evaluation we have tried to test the method in different ways, but it is not possible to foresee all of the possibilities and problems that investigators will encounter. It is entirely possible that some modifications, particularly of the Faunal Indices, will evolve as the method is used. For this purpose the authors will try to be available for consultation at least in the early historical stages of the method's use.

Investigators will undoubtedly be concerned about the time requirements of the procedure. As an indication of the time required for the field work, we

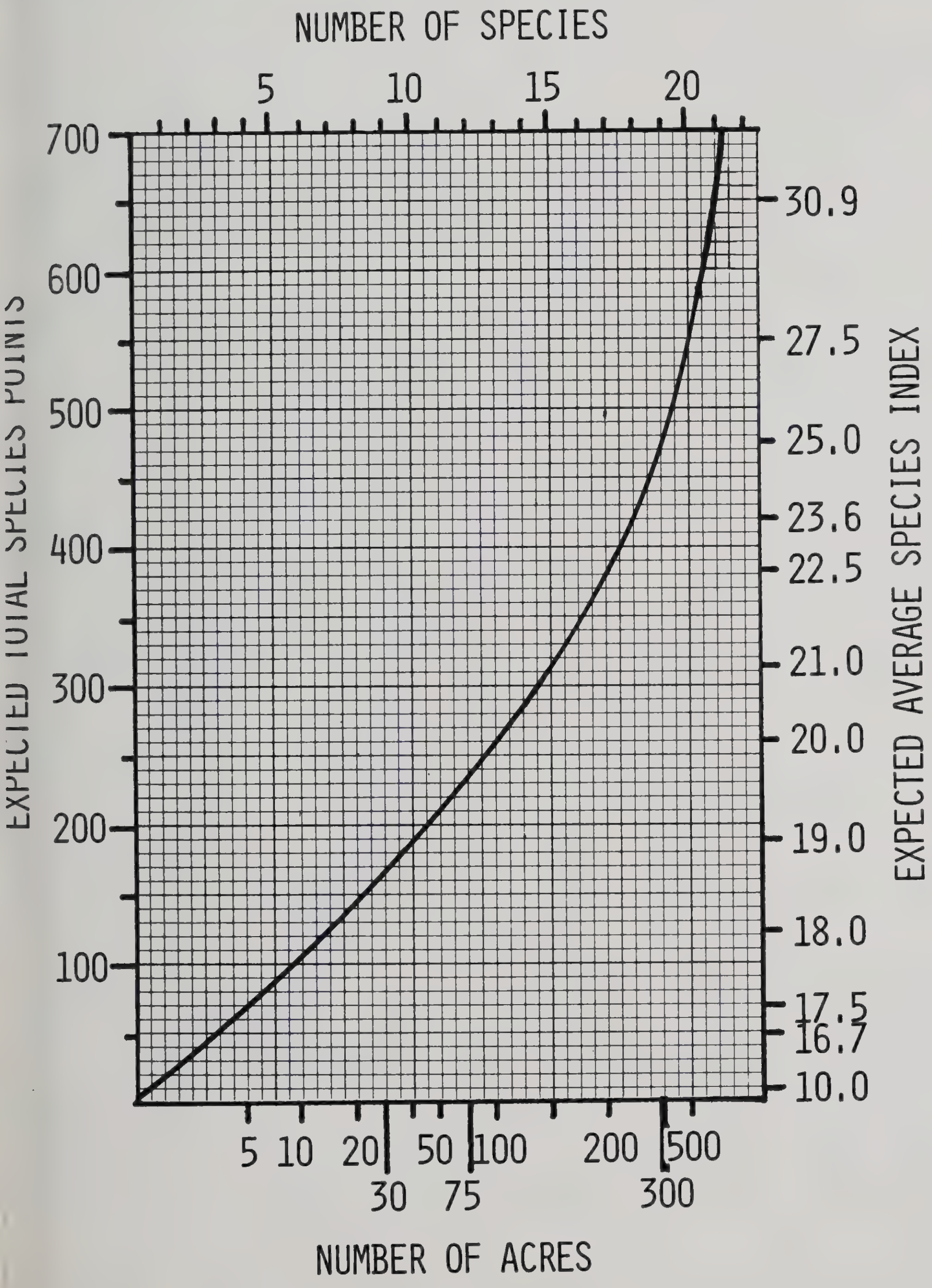

Fig. 15. — Relationship of numbers of species and their assigned index values (based on population levels and habitat specialization) to acreage censused in grassland (prairie, ungrazed and fallow fields, pastures, and hayfields) habitats in Illinois. The graph line is used to interpret calculated Faunal Indices in evaluating impact areas. See text for explanation.

can refer to our investigation of the test impact area (Table 14). The area of about 644 acres was as complicated in its habitat structure and diversity as any likely to be encountered in the state, with numerous small patches of different habitats. It included about 200 acres familiar to us but which we had never measured or evaluated on any quantitative basis. We did have an aerial photograph of the area (scale: 1 inch to 330 feet) and we used the photograph as recommended in our procedure. The two of us, working as a team, made all of the field measurements of habitats of different ages and acreages, as outlined in the procedure for the Habitat Evaluation Index, in 2 days. Determining the corrected acreages on the photograph and analyzing the data required 2 additional days in the office for the calculation of the HEI for the area.

We did know the birds of the impact area from previous years of observation; so our estimate of the time requirement for the collection of the bird data is based on observations at other, unfamiliar areas. We have estimated that collecting the qualitative bird data will take about twice as long as gathering the field data for the HEI, depending upon the types of habitats present. This estimate was made for an area similar in complexity to our test area. In an area with as much as 50 percent forest cover, the investigator should allow 1–2 days per 100 acres for the collection of the faunal data. The time requirement increases as the percentage of complex habitats, versus simple open field habitats, increases.

LITERATURE CITED

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union. 691 p.

Anderson, R. C., and J. White. 1970. A cypress swamp outlier in southern Illinois. Illinois State Academy of Science Transactions 63(1):6–13.

Arnold, L. E. 1973. Growth of loblolly and shortleaf pine at various spacings in southern Illinois. Pages 47–49 *in* H. A. Cate, editor, Update 73, Dixon Springs Agricultural Center Research Report 1.

Bazzaz, F. A. 1968. Succession on abandoned fields in the Shawnee Hills, southern Illinois. Ecology 49(5):924–936.

Beckwith, S. L. 1954. Ecological succession on abandoned farm lands and its relationship to wildlife management. Ecological Monographs 24(4):349–376.

Booth, W. E. 1941. Revegetation of abandoned fields in Kansas and Oklahoma. American Journal of Botany 28(5):415–422.

Carmean, W. H. 1971. Site index curves for black, white, scarlet, and chestnut oaks in the central states. U. S. Department of Agriculture Forest Service, North Central Forest Experiment Station Research Paper 62. 8 p.

Chittenden, A. K., and P. W. Robbins. 1930. The farm woodlot in Michigan. Michigan State College Agricultural Experiment Station Special Bulletin 196. 28 p.

Clements, F. E., and V. E. Shelford. 1939. Bio-ecology. John Wiley & Sons, Inc., New York. 425 p.

Conard, H. S. 1918. Tree growth in the vicinity of Grinnell, Iowa. Journal of Forestry 16(1):100–106.

Dwight, T. W. 1926. The use of growth charts in place of yield tables. Journal of Forestry 24(4):358–377.

Essex, B. L., and D. A. Gansner. 1965. Illinois' timber resource. U. S. Department of Agriculture Forest Service Resource Bulletin LS-3. 56 p.

Evers, R. A. 1955. Hill prairies of Illinois. Illinois Natural History Survey Bulletin 26(5):368–446.

Fell, E. W., and G. B. Fell. 1957. The gravel-hill prairies of Rock River valley in Illinois. Illinois State Academy of Science Transactions 49:47–62.

Fisher, R. E. 1969. Edwards County surface water resources. Illinois Department of Conservation, Division of Fisheries. 41 p.

Forbes, R. D., and E. L. Demmon. 1929. Volume, yield, and stand tables for second-growth southern pines. U. S. Department of Agriculture Miscellaneous Publication 50. 202 p.

Gevorkiantz, S. R., and H. F. Scholz. 1944. Determining site quality in understocked oak forests. Journal of Forestry 42(11):808–811.

Gilmore, A. R. 1973. Effect of residual soil fertility on wood specific gravity of planted sycamore. Pages 65–66 *in* H. A. Cate, editor, Update 73, Dixon Springs Agricultural Center Research Report 1.

————, L. E. Arnold, and R. A. Young. 1973*a*. Early growth of planted cottonwood on upland soils in southern Illinois as related to residual soil fertility. Pages 62–64 *in* H. A. Cate, editor, Update 73, Dixon Springs Agricultural Center Research Report 1.

————, R. A. Young, and L. E. Arnold. 1973*b*. Response of sweetgum to fertilization in southern Illinois. Pages 59–61 *in* H. A. Cate, editor, Update 73, Dixon Springs Agricultural Center Research Report 1.

Glock, W. S. 1941. Growth rings and climate. Botanical Review 7(12):649–713.

———— 1955 Growth rings and climate. Botanical Review 21(1–3):73–188.

Graber, R. R., and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906–1909 and 1956–1958. Illinois Natural History Survey Bulletin 28(3):383–528.

Griffiths, B. M. 1932. The ecology of Butterby Marsh, Durham. Journal of Ecology 20:105–127.

Hopkins, L. D., R. B. Wood, D. Brochmann, and L. Messina. 1973. Environmental impact statements: a handbook for writers and reviewers. Illinois Institute for Environmental Quality Document 73-8. 202 p.

Illinois Cooperative Crop Reporting Service. 1974. Illinois Agricultural Statistics. Illinois Department of Agriculture and U. S. Department of Agriculture Bulletin 74-1. Springfield, Illinois.

Illinois Department of Conservation and Illinois Nature Preserves Commission. 1972. A directory of Illinois nature preserves. 16 p.

Illinois Department of Transportation, Division of Aeronautics. 1973. Illinois Airport Directory. 150 p.

————, Division of Highways. 1970. Highway mileage. 9 p.

Jones, G. N. 1963. Flora of Illinois. American Midland Naturalist Monograph 7. University of Notre Dame Press, Notre Dame, Indiana. 401 p.

Kershaw, K. A. 1973. Quantitative and dynamic plant ecology. 2d ed. American Elsevier Publishing Company, Inc., New York. 308 p.

King, D. B., and R. K. Winters. 1952. Forest resources and industries of Illinois. University of Illinois Agricultural Experiment Station Bulletin 562. 95 p.

Lamb, G. N. 1915. Willows: their growth, use, and importance. U.S. Department of Agriculture Bulletin 316. 52 p.

Lopinot, A. C. 1973. 1972 Illinois surface water inventory. Illinois Department of Conservation Special Fisheries Report 40. 61 p. + water inventory for each county.

Lorenz, R. W. 1962. The Forestry — one of our first experiments. Illinois Research. Fall, 1962:8–9.

Losche, C. K. 1973. Black walnut growth better on deep, well-drained bottomland soils. U. S. Department of Agriculture Forest Service. North Central Forest Experiment Station Research Note NC-54. 3 p.

Mattoon, W. R. 1915*a*. Life history of shortleaf pine. U. S. Department of Agriculture Bulletin 244. 46 p.

________. 1915*b*. The southern cypress. U. S. Department of Agriculture Bulletin 272. 74 p.

Mohlenbrock, R. H. 1973. Forest trees of Illinois. Illinois Department of Conservation Division of Forestry. 178 p.

Odum, E. P. 1953. Fundamentals of ecology. W. B. Saunders Company, Philadelphia. 384 p.

Penfound, W. T. 1953. Plant communities of Oklahoma lakes. Ecology 34(3):561–583.

Rand McNally. 1971. Handy railroad atlas of the United States. Rand McNally and Company, Chicago. 64 p.

Rennels, R. G. 1971. Sassafras plantation is well worth a traveler's stop. Illinois Research 13(2):12–13.

Robbins, W. J. 1921. Precipitation and the growth of oaks at Columbia, Missouri. University of Missouri Agricultural Experiment Station Research Bulletin 44. 21 p.

Sampson, H. C. 1921. An ecological survey of the prairie vegetation of Illinois. Illinois State Natural History Survey Bulletin 13(16):523–577.

Sanderson, G. C., R. L. Westemeier, and W. R. Edwards. 1973. Acquisition and management of prairie chicken sanctuaries in Illinois. Pages 59–79 *in* W. D. Svedarsky and T. Wolfe, editors, The prairie chicken in Minnesota. University of Minnesota, Crookston.

Schramm, P., editor. 1970. Proceedings of a symposium on prairie and prairie restoration. Knox College Biological Field Station Special Publication 3. 66 p.

Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States: their extent and their value to waterfowl and other wildlife. U. S. Department of the Interior Fish and Wildlife Service Circular 39. 67 p.

Shelford, V. E. 1954. Some lower Mississippi valley flood plain biotic communities; their age and elevation. Ecology 35(2):126–142.

Smith, R. C. 1973. Returns from two systems of multicropping. Pages 106–110 *in* Black walnut as a crop. U. S. Department of Agriculture Forest Service General Technical Report NC-4.

Splettstaszer, M. A., and A. O. Manke. 1955. Wetlands inventory of Illinois. U. S. Department of the Interior Fish and Wildlife Service, Office of River Basin Studies. Minneapolis, Minnesota. 19 p. + appendix.

Steyermark, J. A. 1940. Studies of the vegetation of Missouri — I. Natural plant associations and succession in the Ozarks of Missouri. Field Museum of Natural History. Botanical Series 9(5):347–475.

Studhalter, R. A. 1955. Tree growth I. Some historical chapters. Botanical Review 21(1–3):1–72.

Tester, J. R., and W. H. Marshall. 1961. A study of certain plant and animal interrelations on a native prairie in northwestern Minnesota. University of Minnesota Museum of Natural History Occasional Papers 8. 51 p.

Thomson, J. W., Jr. 1940. Relic prairie areas in central Wisconsin. Ecological Monographs 10(4):685–717.

U. S. Department of Agriculture Forest Service. 1968. Timber management plan. Shawnee Working Circle July 1, 1969–June 30, 1978. U. S. Government Printing Office. 23 p. + appendixes.

U. S. Department of Commerce Bureau of the Census. 1960. Area measurement reports. Areas of Illinois: 1960. 27 p.

________. 1972. 1969 census of agriculture. Part 12. Illinois. Volume 1. Area Reports. Sections 1–2.

Veatch, J. O. 1933. Some relationships between water plants and water soils in Michigan. Michigan Academy of Science, Arts and Letters 17:409–413.

Voigt, J. W., and R. H. Mohlenbrock. 1964. Plant communities of southern Illinois. Southern Illinois University Press, Carbondale. 202 p.

Weaver, J. E. 1961. Return of midwestern grassland to its former composition and stabilization. Western Michigan University, C. C. Adams Center for Ecological Studies Occasional Papers 3. 15 p.

Williamson, A. W. 1913. Cottonwood in the Mississippi valley. U. S. Department of Agriculture Bulletin 24. 62 p.

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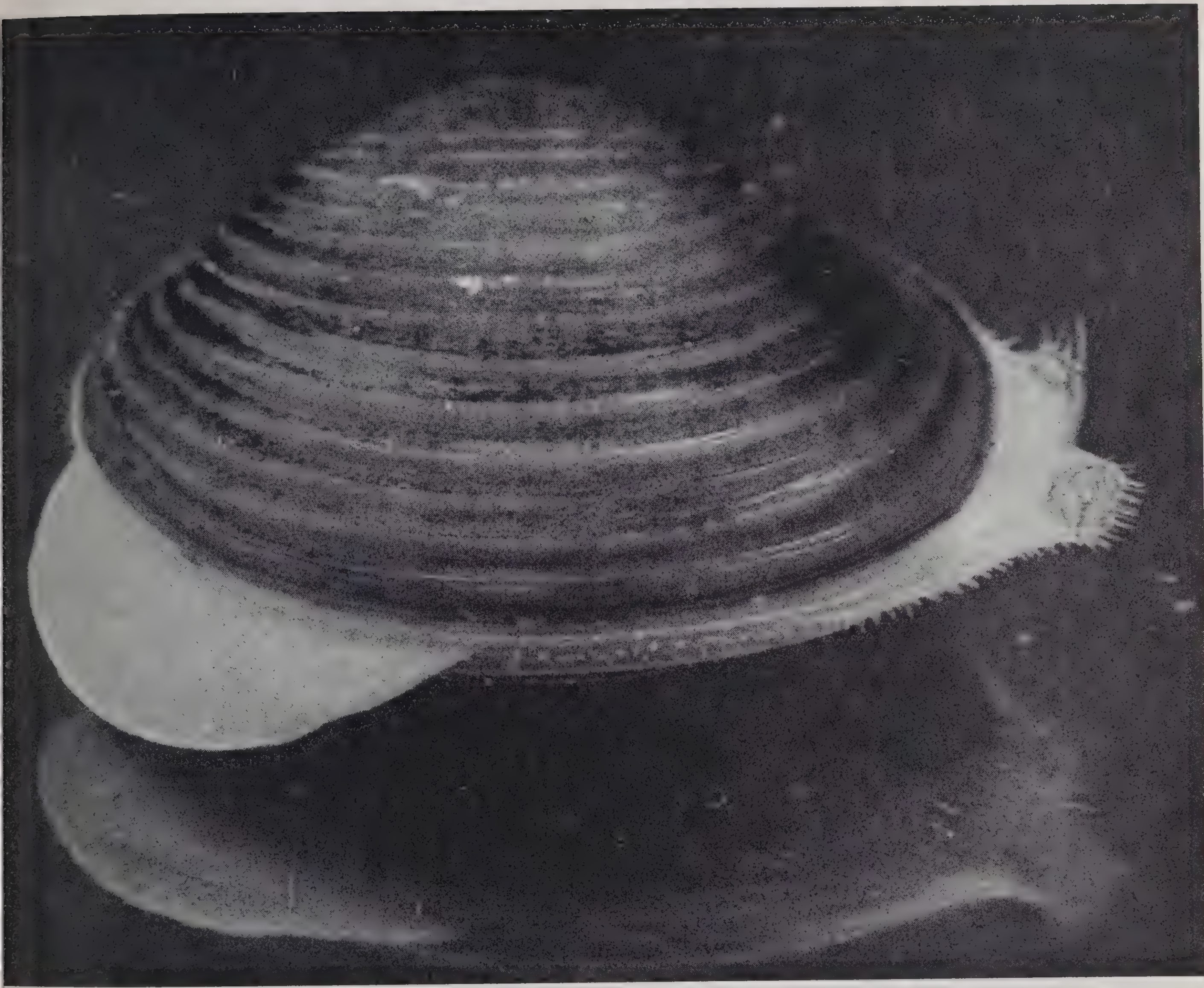

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Natural History Survey Division

Cover Photograph. — A live Asiatic clam, *Corbicula manilensis,* in dechlorinated municipal water containing no added potassium. The photograph was taken by mounting a camera and flash unit over a glass dish containing the clam and water. The room was darkened for several hours during which time the clam opened its shell and extended its foot and siphons. An instant after th photograph was taken the clam retracted its foot and siphons in response to the light flash.

Effects of Potassium on Adult Asiatic Clams, *Corbicula manilensis*

Kevin B. Anderson
Carl M. Thompson
Richard E. Sparks
Anthony A. Paparo

Since its introduction into North America in 1938, the ecological and economic impacts of the Asiatic clam, *Corbicula manilensis,* have become increasingly important. Although the ecological consequences of the Asiatic clam have not yet been fully evaluated, Sinclair & Isom (1963:15) suggested the possibility that the Asiatic clam could displace the native sphaeriid fauna. The clams have also become important by entering food chains. At Lake Sangchris, Sangamon County, Illinois, diving and dabbling ducks ingest Asiatic clams in the wild (Personal communication, William L. Anderson, Associate Wildlife Specialist, Illinois Natural History Survey, October 1975). Fish species known to feed on *Corbicula m.* include the blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), carp (*Cyprinus carpio*), redear sunfish (*Lepomis microlophus*), freshwater drum (*Aplodinotus grunniens*) (Sinclair & Isom 1963:16), and sturgeon (Ingram 1959:369).

The economic impact of the clams is serious. Sinclair (1971:11) stated that the Asiatic clam was the most costly liability of all exotic mollusca in North America. In the Midwest, the biggest problem caused by these clams is their accumulation in reservoirs, condenser pipes, and water intake structures. In some cases, buildups have become so great as to necessitate costly plant shutdowns for cleaning operations. Ingram (1959:364–366) reviewed a number of problems associated with this alien mollusk.

An uninvestigated area of study concerns the effects of metal ions on the Asiatic clam and whether metals could affect the distribution of the clams or be used for purposes of control. The objective of this research was to measure the sublethal and lethal effects of potassium on *Corbicula m.*

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METHODS AND MATERIALS

Clams

The mature *Corbicula manilensis* used in this experiment were collected on 23 October 1975 at the Granite City Steel Company, Granite City, Illinois. The organisms had accumulated in a reservoir containing water used for cooling purposes. They were transported to the Illinois Department of Conservation Field Headquarters at Havana, Illinois, where they were acclimated in well water for 6 weeks in a 600-liter tank. Water temperature in the holding tank was maintained at 17° ± 1° C. The clams were fed once a week with Gordon's formula (Innes:33), which was finely ground by mixing with water in a Waring blender.

Asiatic clams used in the bioassay averaged 12.6 mm in shell length (range, 11–14 mm) and 565 mg in weight.

Testing Apparatus

A proportional diluter (Mount & Brungs 1967) was used to deliver a continuous flow of well water or well water plus potassium to the test chambers. The test chambers were 19-liter glass jars immersed in a circulating water bath to minimize temperature fluctuations during tests. Groups of clams were placed in "clam cages," each consisting of a Petri dish (100-mm diameter) covered with a plastic lid. A 50-mm diameter hole was cut in the center of the lid. This design allowed water to circulate in the clam cages and kept the clams from crawling out. The cages could be removed and placed under a dissecting microscope without greatly disturbing the clams.

The flow rate of the diluter was adjusted to 3.57 liters per hour, allowing 90-percent replacement of the test solution in 11 hours.

Duplicate test chambers were used for each of the five test concentrations and the controls — 12 chambers in all.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12, and is a contribution from the Section of Aquatic Biology, Illinois Natural History Survey, where Mr. Kevin B. Anderson is a Research Assistant, Mr. Carl M. Thompson is a Junior Professional Scientist, and Dr. Richard E. Sparks is an Assistant Aquatic Biologist. Mr. Anderson is also a graduate student at Western Illinois University, Macomb. Dr. Anthony A. Paparo is an Associate Professor, Department of Zoology and School of Medicine, Southern Illinois University, Carbondale.

Water Chemistry

Dilution water for this experiment was well water with these properties: lead, 0.05 mg/liter; zinc, 0.07 mg/liter; copper, 0.08 mg/liter; hardness, 247–263 mg/liter as $CaCO_3$; total alkalinity, 151–161 mg/liter as $CaCO_3$. Heavy metal concentrations in the well water were measured with an atomic absorption unit once during the experiment. Hardness and total alkalinity were measured by standard methods (Taras et al. 1971). The temperature, pH, and dissolved oxygen of the test chambers were measured with meters daily during the experiment (Table 1).

Table 1. — Test conditions during the potassium bioassay with Asiatic clams. (Means are given in the table, with ranges in parentheses; a single composite sample was analyzed for potassium; therefore, no range is presented.)

Test Chamber	Potassium (mg/liter)	pH	Dissolved Oxygen (mg/liter)	Temperature (Celsius)
9 & 10	458	7.91 (7.85–7.95)	8.8 (8.5–9.1)	16.9 (16.5–17.1)
1 & 2	246	7.89 (7.85–7.90)	8.7 (8.3–9.0)	16.9 (16.5–17.1)
3 & 4	149	7.89 (7.85–7.90)	8.8 (8.3–9.1)	16.9 (16.5–17.1)
5 & 6	98	7.88 (7.85–7.90)	8.7 (8.3–9.0)	16.9 (16.5–17.1)
7 & 8	44	7.88 (7.85–7.90)	8.8 (8.5–9.2)	16.9 (16.5–17.1)
11 & 12	7.25[a]	7.80 (7.75–7.85)	8.6 (8.3–9.0)	16.9 (16.5–17.1)

[a] Dilution water with no added potassium. Dilution water had no noticeable effects on clams during the acclimation and test periods.

A concentrated stock solution of reagent-grade potassium chloride was prepared in distilled deionized water to supply the diluter. Fresh stock solution was prepared daily during the test. The diluter was adjusted to provide concentrations of 458, 246, 149, 98, and 44 mg of potassium per liter of water in the test chambers and to provide dilution water containing no added potassium to two chambers which served as controls. A composite water sample of each toxicant level, consisting of aliquots removed daily, was acidified with concentrated hydrochloric acid to a pH of 1 and subsequently was analyzed at the Illinois Natural History Survey chemical laboratories by flame-emission spectrophotometry. The dilution water was similarly sampled and analyzed, and it contained 7.52 mg of potassium per liter of water (Table 1).

Response Criteria

In this study we investigated 10 responses, of which three provided readily determined, reliable endpoints. One response is referred to as foot immobilization. This is a condition in which the clam's foot is extended but does not respond to gentle prodding. The shell either closed tightly on the foot or gaped slightly. The second response was gaping. Observations of these two sublethal responses were made after 5, 12, 24, 36, 48, 72, and 96 hours of exposure to potassium. These sublethal responses are considered significant for reasons described in the discussion.

The third response was death. A preliminary investigation was carried out to determine the criteria for death. A lack of response to prodding of the extended foot, a lack of response to prodding of the body when the shell gaped slightly, and a lack of a closing response when closed shells were gently twisted open with a knife blade were all shown to be insufficient criteria for death. It was found that some clams not responding to these stimuli recovered after being placed in clean water. To determine precisely which clams were dead, a method suggested by Sinclair (1963:9) was used. Four clam cages, each containing 10 clams, were used in each test chamber. One clam cage was removed from each test chamber after 24, 48, 72, and 96 hours of potassium exposure. After removal, the clams in each cage were rinsed with dilution water, and the cage was put back into the acclimating tank. They were inspected 1 week later at which time the dead clams could easily be distinguished by their widely gaping shells and decaying body tissue. We also periodically observed the clams removed after 96 hours for signs of recovery from foot immobilization.

Response and Toxicity Curves

Although the basic method of Sprague (1973:8–23) is usually used to determine lethal thresholds, it was equally valuable in determining response thresholds. Instead of determining LC50's (the concentrations lethal to 50 percent of the test organisms) at each observation time, EC50's (the concentrations producing an effect on 50 percent of the test organisms) were determined by observing the percentage of clams exhibiting the sublethal responses. The EC50's were plotted on graphs with the time required for 50 percent of the clams to exhibit foot immobilization or gaping on the vertical axis and the concentration of potassium on the horizontal axis. The resulting curves were the foot-immobilization response curve (Fig. 1) and the gaping response curve (Fig. 2).

Mortality in the 96-hour exposure group was used to determine a 96-hour LC50 for potassium. At shorter exposure times the data were insufficient for such an analysis (i.e., the mortality rate was too low). The maximum likelihood estimation of Finney (1971:50–66) was used to fit the line to the points. The 95-percent confidence limits and slope function of the line were determined by methods given by Litchfield & Wilcoxon (1949:101–106).

RESULTS AND DISCUSSION

Table 1 gives the test conditions and potassium concentrations throughout the course of the bioassay. Fig. 1 indicates that potassium acts rather quickly to produce foot immobilization, with the vertical asymptote being reached within 48 hours. The response threshold is the point on the graph where the vertical asymptote inter-

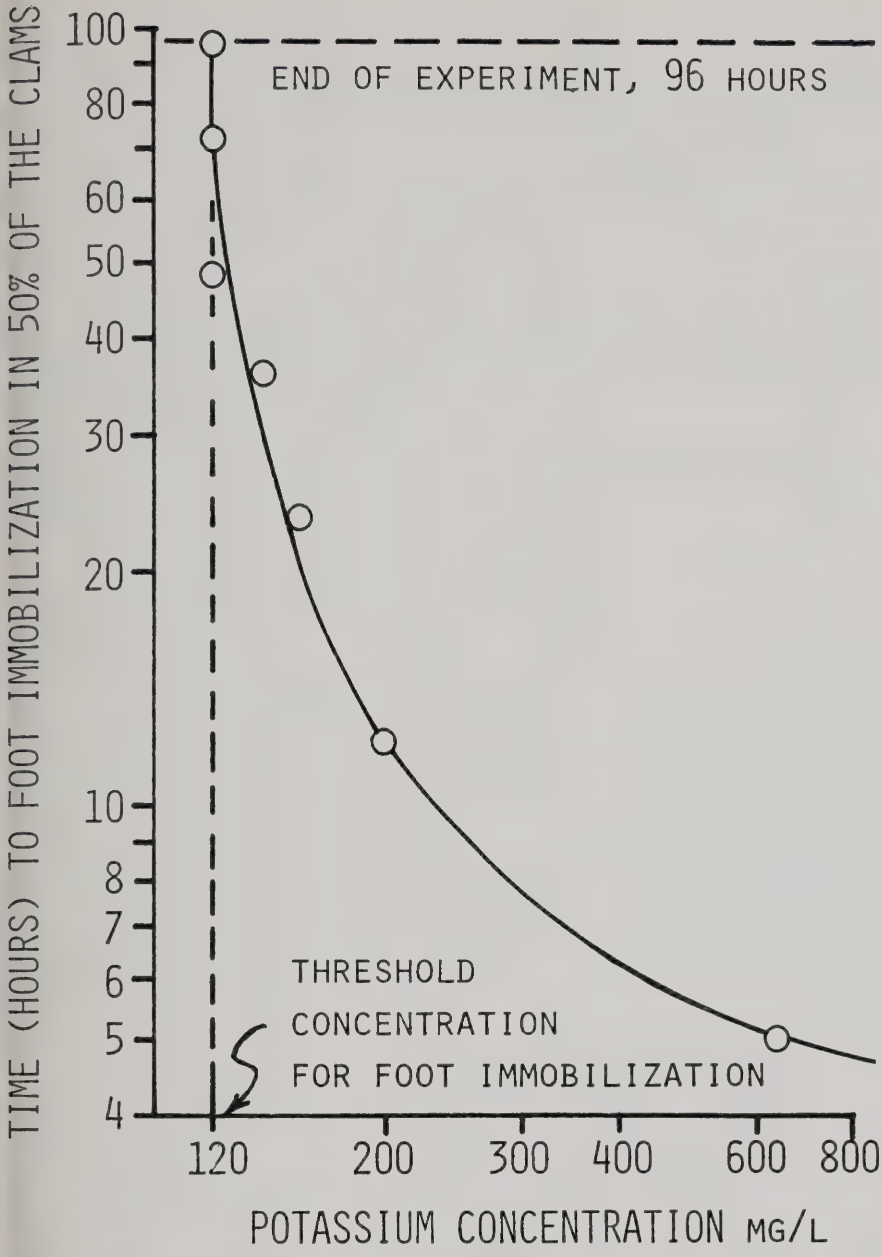

Fig. 1. — Foot-immobilization response curve. The 5-hour EC50 of approximately 600 mg of potassium per liter of water is an extrapolated value. After 5 hours foot immobilization had occurred in fewer than 50 percent of the clams exposed to the highest concentration of potassium (458 mg/liter). All other EC50's plotted on this graph were determined by interpolation, i.e., more than 50 percent of the clams had responded at the high concentrations and fewer than 50 percent had responded at the lower concentrations.

cepts the concentration axis. The threshold concentration of potassium for the foot immobilization response of *Corbicula m.* is 120 mg per liter of water. Fig. 2 shows that gaping also occurs within 48 hours of exposure to potassium and that the threshold concentration is probably close to 190 mg of potassium per liter of water. The gaping response curve appears to be reaching an asymptote at 190 mg/liter after 96 hours of exposure, but a longer exposure period than the 96 hours used in our experiments would be necessary to confirm the threshold. It is important to note that 85 percent of the clams exposed to 458 mg of potassium per liter of water did not gape; rather, they clamped tightly shut, sometimes pinching the extended and immobilized foot (Fig. 3).

The foot-immobilization response is considered significant because it results in direct exposure to the toxicant of a portion of the clam's body. Gaping likewise permits contact between the tissues of the clam and chemicals in the surrounding water. One of the problems in attempts to control the Asiatic clam has been its ability to withstand slug dosing of chemicals. The resistance is in part attributed to the clam's habit of tightly closing its shell when exposed to an irritant. Thus, a high concentration of a toxicant and a long exposure time are required to control the adult clam effectively. Although additional research is needed, the foot-immobilization and gaping responses might prove useful in the control of the clam. Exposing the clam to potassium could be accompanied or followed by exposure to a molluscacide or other control agent, and thus a shorter exposure time or a reduced concentration of the toxic agent might be sufficient.

The 96-hour LC50 was 225 mg of potassium per liter of water. The 95-percent confidence limits for this value were 157–322 mg of potassium per liter of water; the

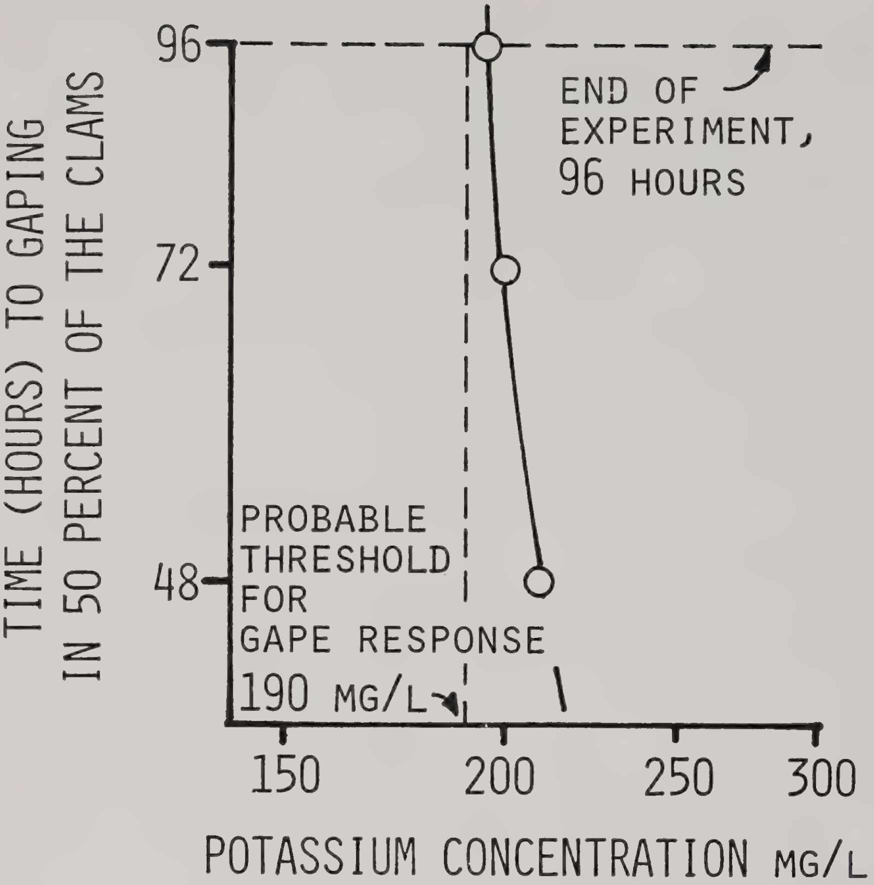

Fig. 2. — Gaping response curve. The threshold concentration of potassium required to produce the gaping response appears to be 190 mg/liter although a longer exposure period than the 96 hours used in our experiments would be necessary to confirm the threshold. Clams exposed to 458 mg of potassium per liter of water did not gape, but clamped tightly shut.

slope function was 1.5056 for the line used to derive the 96-hour LC50. In comparison with fish and snails, adult *Corbicula m.* are sensitive to potassium. For example, the 96-hour LC50's for several test organisms exposed to potassium chloride, as reported in McKee & Wolf (1963: 244), are: mosquitofish, *Gambusia affinis,* 920 mg/

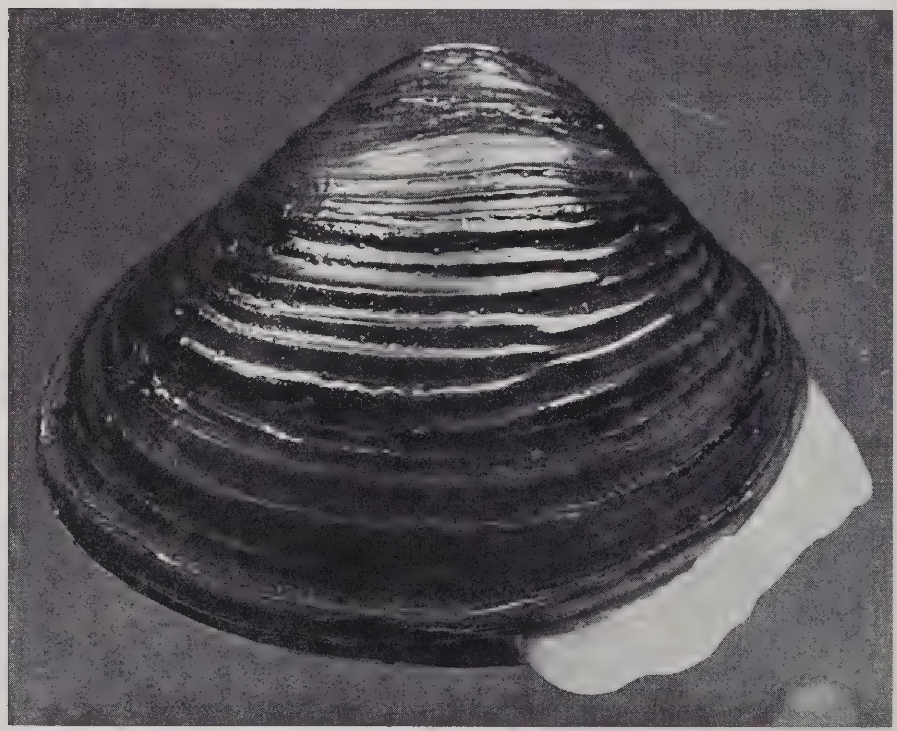

Fig. 3. — *Corbicula manilensis* under potassium stress. The partially extended foot is tightly clamped between the valves, and the foot has a puckered appearance. The clam did not retract its foot in response to a flash of light or to handling.

liter; bluegill, *Lepomis macrochirus,* 2,010 mg/liter; and the snail, *Physa heterostropha,* 940 mg/liter. Unfortunately, other bivalves appear to be more sensitive to potassium. Imlay (1973:104) found that 11 mg of potassium per liter of water was lethal to 90 percent of *Actinonaias carinata, Lampsilis radiata siliquoidea,* and *Fusconaia flava* in 36–45 days of exposure, and 7 mg of potassium per liter of water was fatal to the latter two species in about 8 months. He also compared the distribution of freshwater mussels with potassium levels in 49 U.S. rivers, and on the basis of his findings, he predicted that the maximum safe level for most freshwater mussels is 4–10 mg of potassium per liter of water. It might be possible to use potassium alone or in combination with a molluscacide to treat troublesome populations of Asiatic clams within intake structures or water systems during shutdowns for cleaning or maintenance without damaging other organisms in the surrounding environment. A potassium concentration could be selected that would be high enough to affect Asiatic clams within the plant but low enough to be diluted to nontoxic levels when discharged into the environment.

It is possible that potassium levels in rivers could limit the distribution of *Corbicula m.* although more research is required to determine the chronic effects of potassium on this mollusk.

LITERATURE CITED

Finney, D. J. 1971. Probit analysis. 3rd ed. Cambridge University Press. 333 p.

Imlay, M. J. 1973. Effects of potassium on survival and distribution of freshwater mussels. Malacologia 12(1):97–113.

Ingram, W. M. 1959. Asiatic clams as potential pests in California water supplies. American Water Works Association Journal 51(3):363–370.

Innes, W. T. Exotic aquarium fishes. Innes Publications. 541 p.

Litchfield, J. T., and F. Wilcoxon. 1949. A simplified method of evaluating dose-effect experiments. Journal of Pharmacology and Experimental Therapeutics 96:99–113.

McKee, J. E., and H. W. Wolf, eds. 1963. Water quality criteria. 2nd ed. The Resources Agency of California, State Water Quality Control Board, Sacramento. 548 p.

Mount, D. I., and W. A. Brungs. 1967. A simplified dosing apparatus for fish toxicology studies. Water Research 1:21–29.

Sinclair, R. M. 1963. Effects of an introduced clam (*Corbicula*) on water quality in the Tennessee River Valley. Second Annual Sanitary Engineering Conference, Vanderbilt University. Tennessee Department of Public Health, Tennessee Stream Pollution Control Board, Nashville. 14 p.

———. 1971. Annotated bibliography on the exotic bivalve *Corbicula* in North America, 1900–1971. Sterkiana 43:11–18.

———, and B. G. Isom. 1963. Further studies on the introduced Asiatic clam (*Corbicula*) in Tennessee. Tennessee Department of Public Health, Tennessee Stream Pollution Control Board, Nashville. 75 p.

Sprague, J. B. 1973. The ABC's of pollutant bioassay using fish. Pages 6–30 *in* J. Cairns, Jr., and K. L. Dickson, eds., Biological methods for the assessment of water quality. American Society for Testing and Materials, Philadelphia.

Taras, M. J., A. E. Greenberg, R. D. Hoak, and M. C. Rand, eds. 1971. Standard methods for the examination of water and wastewater. 13th ed. American Public Health Association, Washington, D.C. 874 p.

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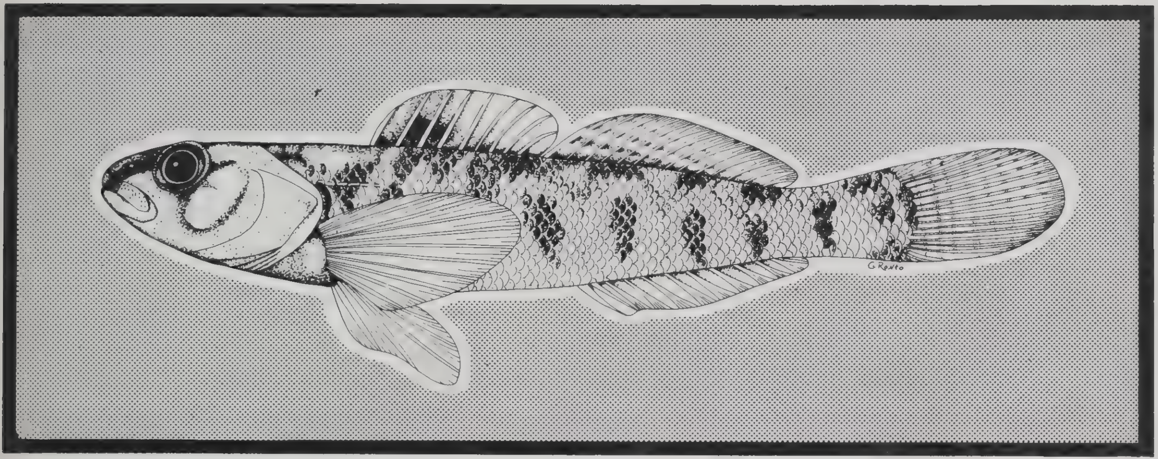
THE LIFE HISTORY OF THE SLABROCK DARTER, *Etheostoma smithi*, in Ferguson Creek, Kentucky

Lawrence M. Page - Brooks M. Burr



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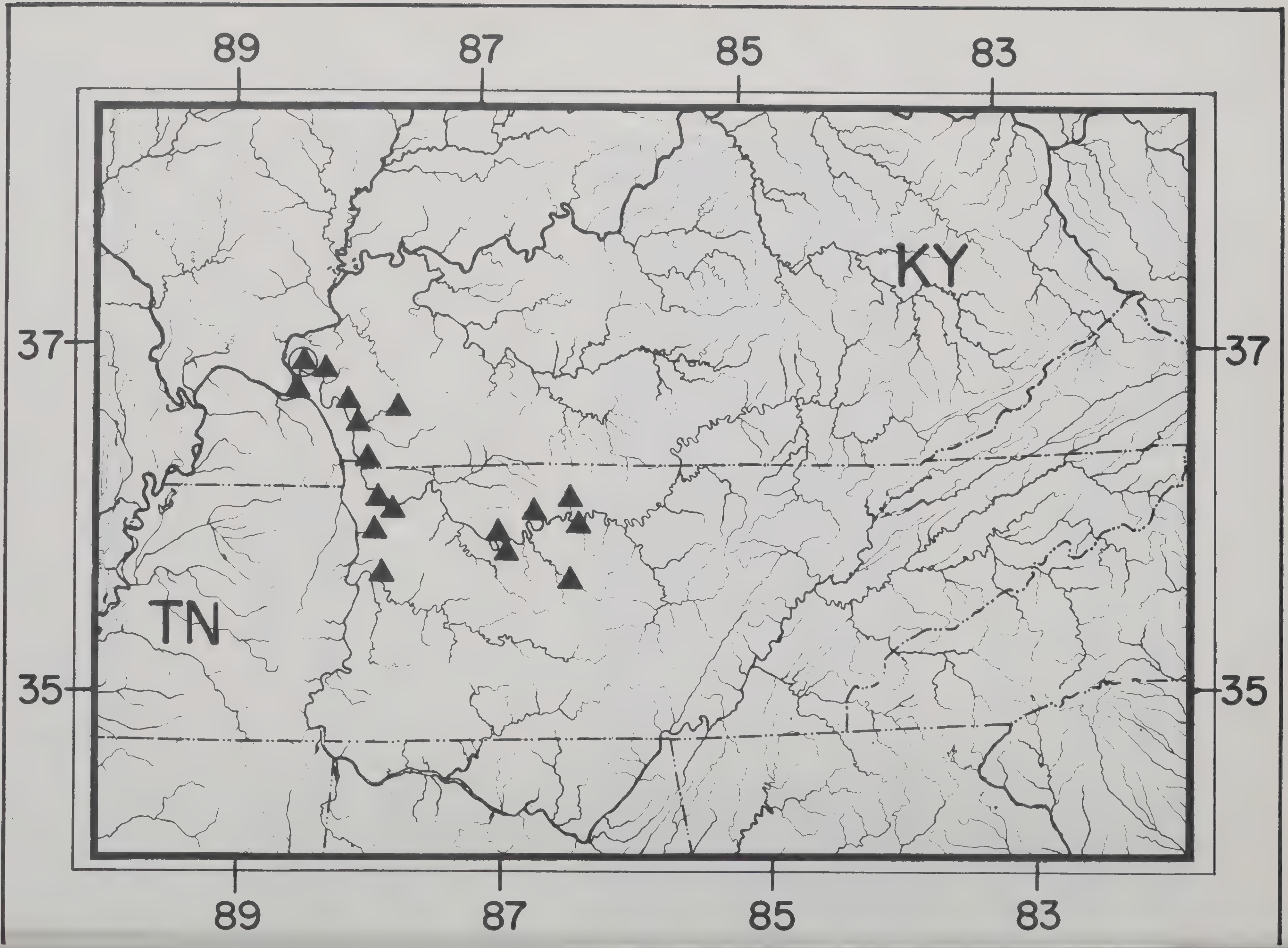
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THE LIFE HISTORY OF THE SLABROCK DARTER, *ETHEOSTOMA SMITHI*, IN FERGUSON CREEK, KENTUCKY

Lawrence M. Page and Brooks M. Burr

This is the third of three life-history reports on species of the subgenus *Catonotus* studied in southeastern Illinois and the adjacent area of Kentucky between October 1970 and April 1974. The first two reports were on *Etheostoma squamiceps* (Page 1974) and *E. kennicotti* (Page 1975*a*).

Etheostoma smithi was recently described by Page & Braasch (1976) from specimens collected in Ferguson Creek, Livingston County, Kentucky. *E. smithi* is distributed in the lower Cumberland and Tennessee river systems (Fig. 1). The closely related *E. obeyense* is distributed in the middle Cumberland River system, and until the description of *E. smithi*, the two forms were considered conspecific. This misinterpretation is reflected in the recent discussion by Page (1975*b*) of spawning observations made on "*E. obeyense*"; the population on which these observations were made is the one studied for this report and is actually *E. smithi.*

We are indebted to Douglas W. Schemske, Philip W. Smith, and Lewis J. Stannard for aid in collecting specimens, and to Dr. Smith for counsel on various matters. The illustrations were prepared by Craig W. Ronto and Illinois Natural History Survey Illustrator Lloyd LeMere and Survey Photographer Larry Farlow. The manuscript was typed by Bernice P. Sweeney and Alice Adams and edited for publication by Robert M. Zewadski, Technical Editor of the Survey. Dr. Chu-Fa Tsai, University of Maryland, served as guest reviewer.

STUDY AREA AND METHODS

The study area, Ferguson Creek in Livingston County, Kentucky (Fig. 1), is the same area described in the report on *E. squamiceps* (Page 1974: 3–4). Ferguson Creek is a small tributary of the lower Cumberland River and consists mainly of shallow slab-rock pools (Fig. 2) and slab riffles and a few deeper sand-bottomed pools.

The methods of study were the same as those used in the study of *E. squamiceps* (Page 1974: 4–5) except that aging to month was done by using May, the month of the greatest breeding activity in the study area, as month zero. The study of *E. smithi* began on 22 April 1971 and terminated on 19 June 1973. A total of 886 specimens was preserved and

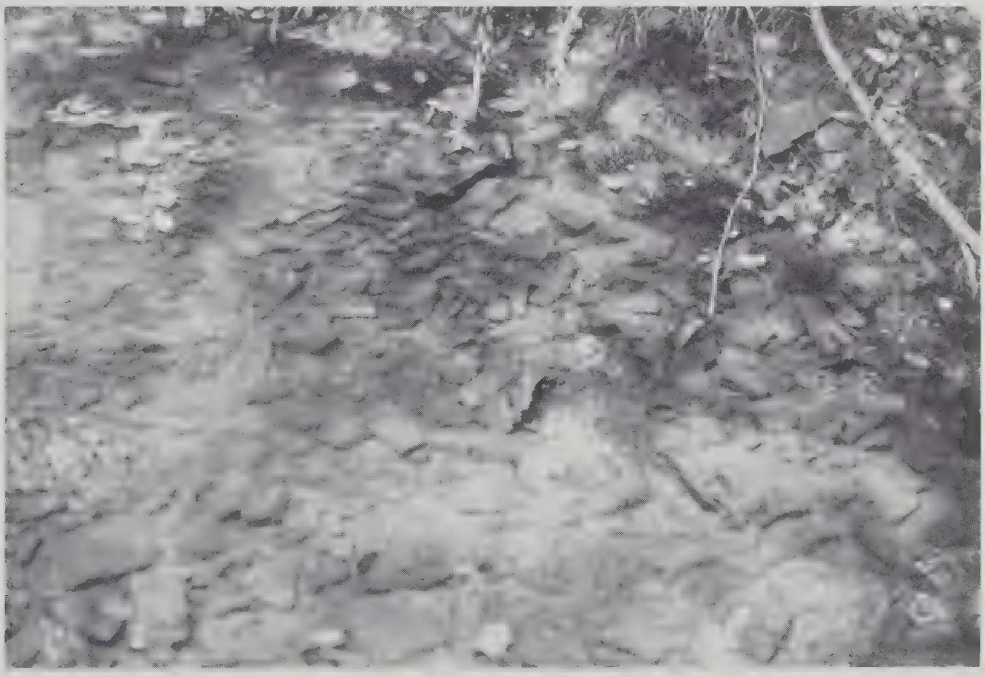

Fig. 2.—Slab pool in Ferguson Creek, Livingston County, Kentucky.

Cover Illustration.—*Etheostoma smithi* collected in Ferguson Creek in Livingston County, Kentucky. From a drawing by Craig W. Ronto.

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examined. All specimens were collected during daylight. Unless stated otherwise, measurements in the text are standard lengths. For certain comparisons darters were divided into young (through 12 months) and adult (over 12 months) age groups.

HABITAT

Beginning on 9 September 1971, approximately the same seining effort was expended on each of the three major types of habitat in Ferguson Creek (slab riffles, slab pools, and non-slab pools). In each month in which they were collected, adults showed a distinct preference for pool habitats (Table 1). Adults were rarely found in riffles, and slab pools were preferred to non-slab pools. Young *E. smithi* were less rigid than adults in their habitat preferences; most were found in slab pools, but many were found in non-slab pools and some in slab riffles (Table 1).

Table 1.—Habitat distribution by percentages of *Etheostoma smithi* collected in Ferguson Creek between 9 September 1971 and 19 June 1973.

Month	Number Collected	Percentage of *E. smithi* in Slab Pools	Slab Riffles	Non-Slab Pools
		Adults		
January	21	76	24	0
February	8	63	0	37
March	10	40	20	40
May	1	100	0	0
June	8	50	0	50
July	11	82	0	18
September	31	74	7	19
October	6	100	0	0
November	27	78	0	22
December	7	57	14	29
		Young		
January	119	60	6	34
February	27	59	4	37
March	28	54	7	39
April	18	83	0	17
May	46	65	33	2
July	128	2	1	97
September	65	54	11	35
October	32	75	0	25
November	78	68	3	29
December	21	43	5	52

The preferred habitat of *E. smithi* is best described as shallow, slab-rock pools in the headwaters and upper reaches of streams. The slab rocks on the bottoms of the pools are used as cover. This habitat preference is essentially the same as that of *E. kennicotti* (Page 1975*a*: 3) although *E. smithi* is more often found in non-slab pools.

REPRODUCTION

Reproductive Cycle of the Male

The genital papilla (Fig. 3) and the testes enlarged as the spawning season approached. Testes of nonbreeding males were small and translucent; those of breeding males were large, white, and spongy. Breeding tubercles did not develop. The tissue along the fin spines and rays swelled, but in contrast to *E. flabellare, E. kennicotti,* and *E. squamiceps,* knobs did not develop on the dorsal fins. As in other *Catonotus* species (Page 1975*a*: 5), the flesh on the head and nape became swollen.

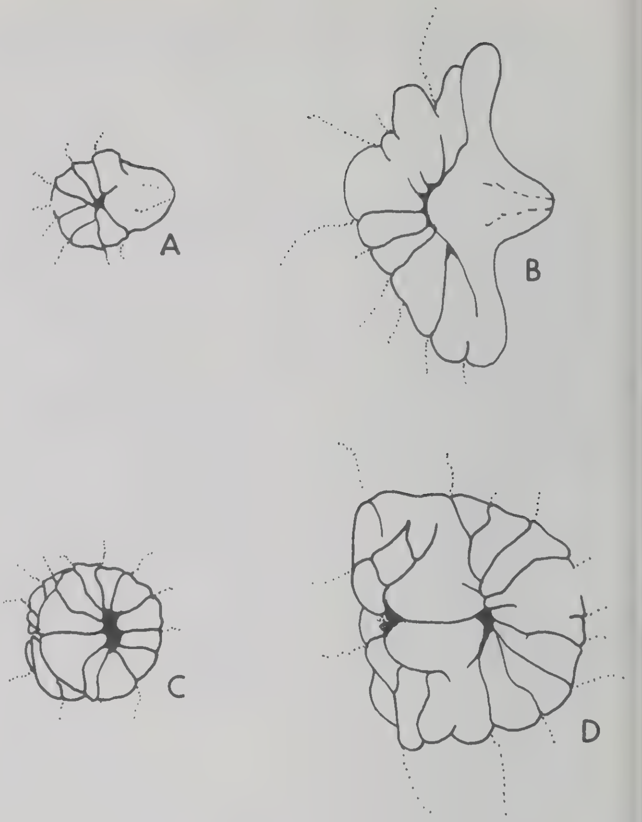

Fig. 3.—Genital papillae of *Etheostoma smithi*. *A,* nonbreeding male; *B,* breeding male; *C,* nonbreeding female; and *D,* breeding female. The breeding specimens were 1 year old, collected on 28 May 1972; the nonbreeding specimens were 1+ years old, collected on 12 September 1972.

At the height of spawning activity males were brightly colored and had developed predominantly red dorsal, caudal, and anal fins. The pectoral fins were reddish medially and had wide black margins ventrally. The anal and lower caudal fins developed blue-black margins, and the black blotch in the first dorsal fin became blacker and larger than in nonbreeding males and in females and was surrounded by red. The entire dorsum was dusky. The breast and pelvic fins were black, and the head was dark and swollen. The black on the head was concentrated in small blotches and interspersed with gold specks, creating a mottling of black and gold. The cheek bar was boldly outlined in gold, and the upper half was bright red. The dark pigment on the sides was concentrated into a series of 10–12 vertical bars.

Beginning in April, males selected cavities under slab rocks in slab pools as future nesting sites and defended them as breeding territories. The cavities were cleaned in the same manner as that described for *E. squamiceps* (Page 1974: 7). All nesting sites found were in slab pools also occupied by breeding and nesting *E. squamiceps.* The pools were in areas where the stream was 1–3 m wide and the current was slow.

One-year-old males that had reached a standard length of about 35 mm were sexually mature and successfully spawned. Males 35.0 mm and longer constituted 33.3 percent of the males collected in April, May, and June. This group presumably represented about the proportion of the male population that spawns each year. Most nests observed were guarded by large males, and as in other *Catonotus* species, the largest males probably did most of the spawning.

Reproductive Cycle of the Female

Females reaching a standard length of at least 28 mm by the end of the spawning season (mid-June) developed mature ova and were potential spawners. As in other darters, the largest females developed mature ova earliest in the breeding season and probably contributed most of the spawning effort.

Small white ova began appearing between September and November, appearing earliest in the largest females. A minimum length of about 20 mm was reached by a female before white ova were discernible. Larger yellow ova were found as early as March in females that measured 30 mm or more, and such ova appeared later in slower growing females. Large, maturing orange ova were present from April to June. Prior to spawning the mature ova became translucent.

The female did not undergo color changes as the breeding season approached and was much less brilliantly colored than the breeding male. The genital papilla enlarged (Fig. 3), beginning about March, and the belly became greatly distended a few days or weeks before spawning.

The largest females produced the largest numbers of mature ova. In 19 females collected in April, May, and June, the number of ova varied from 17 to 69 (Table 2). For these females the relationship between the number of mature ova (F) and the adjusted body weight (W) was $F = 18.00 + 37.39W$, with $r = 0.488$, and between the number of mature ova and the standard length (L) was $\log F = -1.456 + 1.982 \log L$, with $r = 0.483$. Estimates of the number of eggs laid in aquaria by three females (approximately 30-45 mm) were 10 (interrupted spawning?), 80, and 84. Two of these females were larger than those represented in Table 2. Eggs averaged 2.2 mm in diameter, were translucent, and contained a single oil droplet.

Ovaries of postspawning females collected from July through August were very small. A relative increase in ovary size was evident by September, and ovaries continued to enlarge until the spawning

Table 2.—Relationship between size, age, and ovary weight of *Etheostoma smithi* females and the number of mature ova produced. An age of 1 year = 11–13 months, 2 years = 23–25 months.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Age in Years	Ovary Weight in Grams	Number of Mature (Orange or Translucent) Ova
28	0.31	1	0.05	17
28	0.32	1	0.05	27
28	0.32	1	0.06	33
29	0.34	1	0.03	20
30	0.32	1	0.06	31
30	0.34	1	0.04	27
31	0.37	1	0.09	34
31	0.41	1	0.06	19
31	0.41	1	0.08	44
33	0.50	1	0.08	54
33	0.55	1	0.13	53
34	0.51	1	0.07	36
34	0.55	1	0.07	45
35	0.54	1	0.13	49
37	0.70	1	0.05	41
40	0.83	1	0.10	43
41	0.99	1	0.10	37
38	0.85	2	0.12	50
43	1.12	2	0.13	69

[a] Adjusted body weight is the specimen's weight after removal of the ovaries, stomach, intestine, and liver.

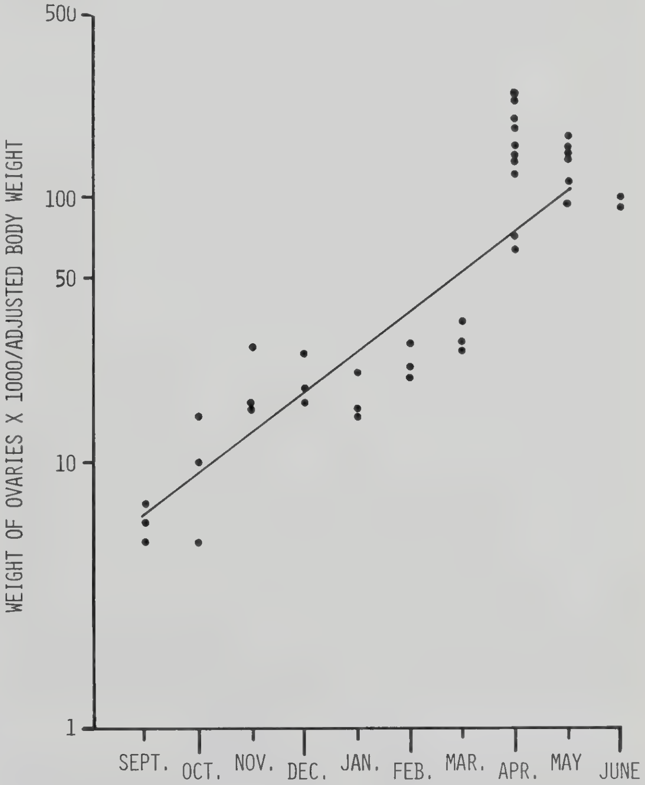

Fig. 4.—Monthly variations in ovarian weight relative to adjusted body weight of 4- to 13-month-old *Etheostoma smithi.* The vertical axis is a logarithmic scale.

period of the following spring (Fig. 4). For the females examined, the relationship between the mean of the weight of the ovaries divided by the adjusted body weight (Y) and the month (X), with September = 1 and May = 9, was log Y = 0.643 + 0.158X, with $r = 0.865$ (Fig. 4). The proportionally largest ovaries (equalling 24.3 percent of the adjusted body weight) were found in a 1-year-old, 31-mm female collected on 22 April 1971. In the 19 females represented in Table 2, ovary-weight-to-adjusted-body-weight ratios ranged from 0.065 to 0.243 and averaged 0.152.

Spawning

At the study area *E. smithi* spawned from late April to mid-June on the undersides of the slab rocks (Fig. 5) previously selected and guarded as nesting territories by the males. Spawning activity was greatest during May, when water temperatures ranged from 15° to 20°C.

Five spawnings of *E. smithi* occurred in our laboratory aquaria; three occurred in the morning and two during the night or very early morning. Aquarium temperatures varied from 18° to 19°C. We observed three of the five spawnings.

The brightly colored breeding males left their nest stones only to feed or to court a nearby female. Courting by the male consisted of lateral displays, with the median fins held erect, and tail wagging. When a female joined a male under his nest stone, the male became extremely active, continuously courting the female and occasionally nudging her with his snout.

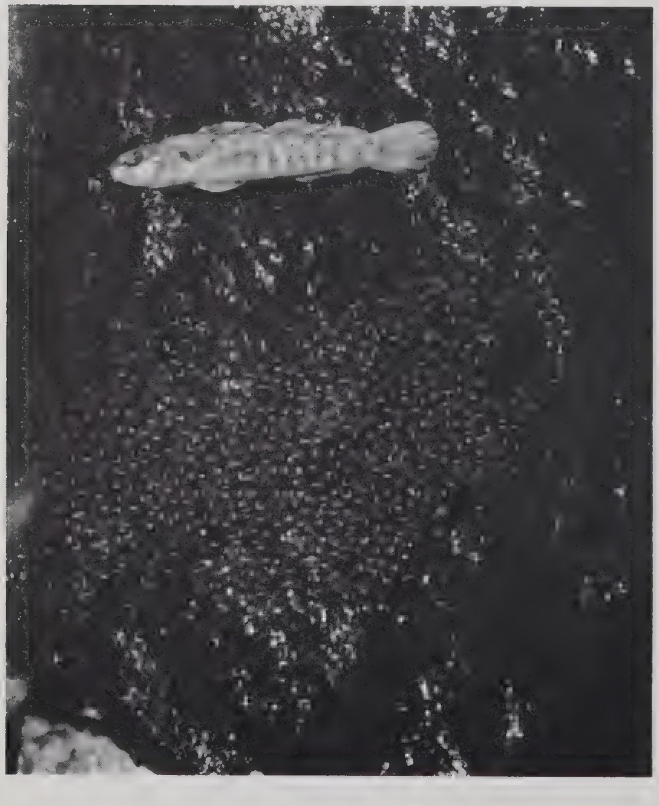

Fig. 5.—*Etheostoma smithi* male and his nest of eggs on the underside of a stone removed from a slab pool in Ferguson Creek on 3 May 1971. The male was guarding the eggs prior to their removal from the pool.

The spawning behavior of *E smithi* was the same as that of *E. kennicotti.* Underneath the nest stone guarded by the male (Fig. 6*A*), the female inverted by rolling to one side and remained inverted throughout the spawning period (Fig. 6*B*). She periodically darted about the nest stone, appearing to examine it and select sites for egg deposition. When not examining the stone or laying eggs, she rested by lowering her back onto the substrate beneath the stone. The male was usually intolerant of a female's remaining right side up under his nest stone.

When laying eggs, the female pressed her genital papilla against the nest stone; she was then joined by the male, who inverted by rolling to one side and positioned himself alongside the female in a head-to-tail (Fig. 6*C*) or head-to-head position. Both trembled as eggs and sperm were released, and then the male returned to an upright position.

The female deposited only one or two eggs during the brief trembling action, which lasted less than 5 seconds, and moved forward slightly as she did so. The eggs were laid in a concentrated area on the stone but never on top of one another. Periods between egg laying varied from about 15 seconds to several minutes.

Four females spawned with the same aquarium-held male. Two of the four began new egg clusters and two added eggs to a cluster begun by another female. As in both *E. squamiceps* (Page 1974: 9) and *E. kennicotti* (Page 1975*a*: 7), all *E. smithi* females after the first to spawn added eggs only to the nest of the male that had already spawned even though at least one other male held a territory in the same aquarium.

Counts and estimates of the numbers of eggs in nine nests of *E. smithi* found in Ferguson Creek were 175, 200, 225, 225, 325, 350, 400, 450, and 600 (mean = 328). Eggs in nests averaged 2.2 mm in diameter.

As in other species of *Catonotus,* males vigorously guarded the nests against potential egg predators and constantly examined the eggs visually, occasionally nipping at the eggs, presumably to remove invading organisms or dead or diseased eggs. The males were very active during this period, darting back and forth and brushing the eggs with their dorsal fins, and retained their bright breeding coloration. Females did not guard the nests.

The spawning behavior of *E. smithi* (referred to as *E. obeyense*) has been compared with that of other species of *Catonotus* by Page (1975*b*).

The same slab pools in Ferguson Creek used as spawning grounds by *E. smithi* were also used by

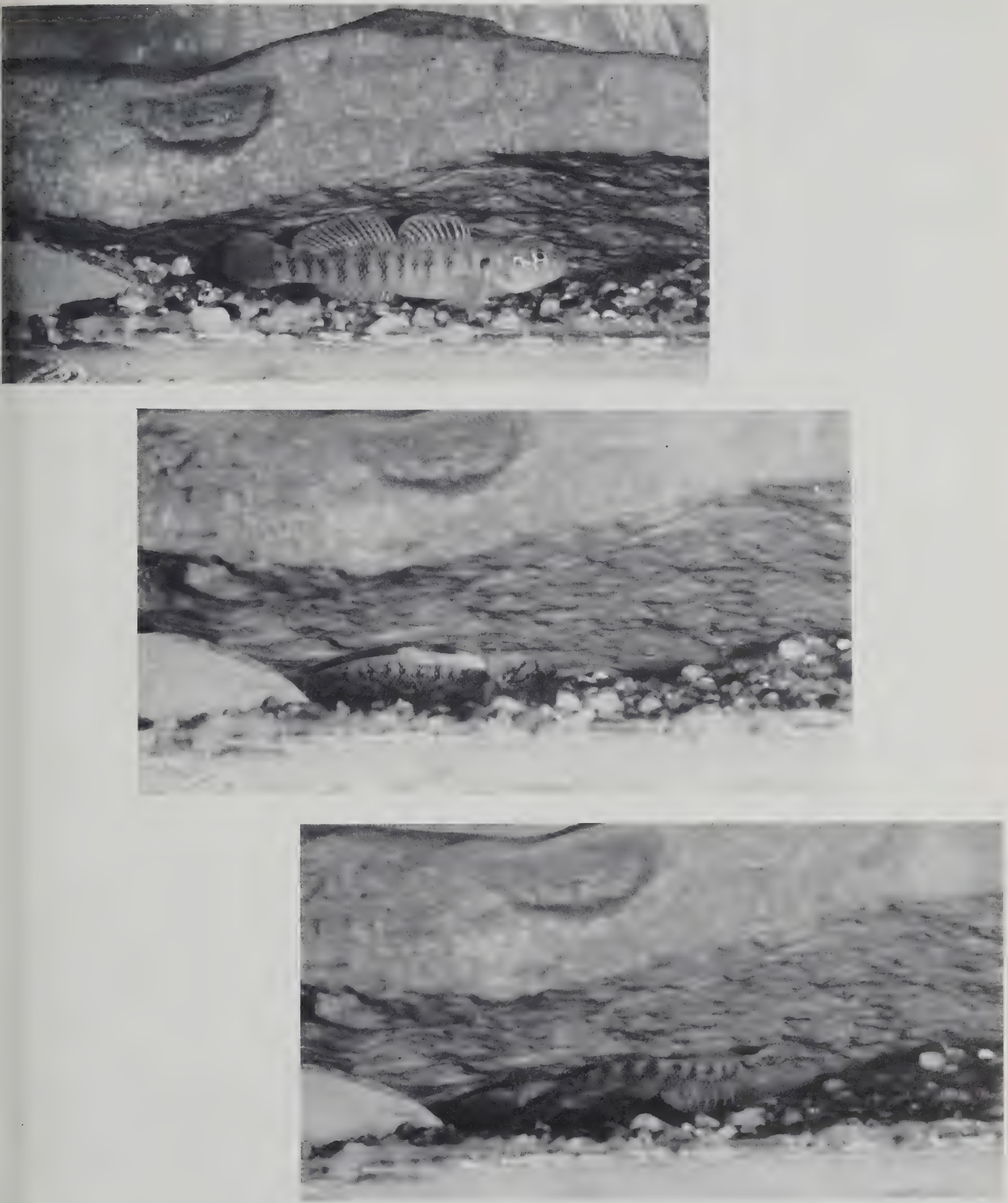

Fig. 6.—*Etheostoma smithi* in aquaria. Top: A breeding male is guarding the cavity beneath a slab stone. Middle: A female has entered the cavity, inverted beneath the stone, and begun laying eggs (the male has momentarily left the cavity). Bottom: Both male and female are inverted as eggs and sperm are released.

E. squamiceps; however, the spawning periods overlapped only in late April and in May. *E. squamiceps* spawned from late March through May with most spawning occurring in April. *E. smithi* spawned from late April to mid-June with most spawning occurring in May. The staggering of spawning periods by species known to spawn on the undersides of stones in the study area has been discussed by Page (1974: 18).

Sexual Dimorphism

Sexual dimorphism in *E. smithi* in territorial behavior, coloration, and size are discussed elsewhere in this paper. In addition, 26 meristic and morphometric characteristics were tested for sexual dimorphism in 25 specimens, each more than 33 mm long, from Ferguson Creek. Of these 26 characteristics, four were found to be sexually dimorphic: males have proportionally longer second dorsal, anal, and caudal fins ($P < 0.005$), and proportionally deeper caudal peduncles ($P < 0.025$).

DEVELOPMENT AND GROWTH

Eggs incubated in aquaria at 13° C (55° F) hatched in 708–732 hours (29.5–30.5 days), and at 21° C (70° F) they hatched in 300–324 hours (12.5–13.5 days). Eggs incubated at 6° C (43° F) and at 27° C (81° F) died before hatching.

Hatchlings of *E. smithi* averaged 6.7 mm in total length and were mostly translucent. As in other *Catonotus* species, the lower jaw and pectoral fins were well developed (Fig. 7*A*). Melanophores were mostly restricted to the yolk sac. Three-day-old larvae (Fig. 7*B*) averaged 7.2 mm in total length and were quite similar morphologically to 3-day-old *E. kennicotti* larvae. Median and pectoral fin rays were evident. At 8 days an aquarium-raised juvenile was 7.5 mm in total length, had partially lost its transparency, and had small pelvic fins (Fig. 7*C*).

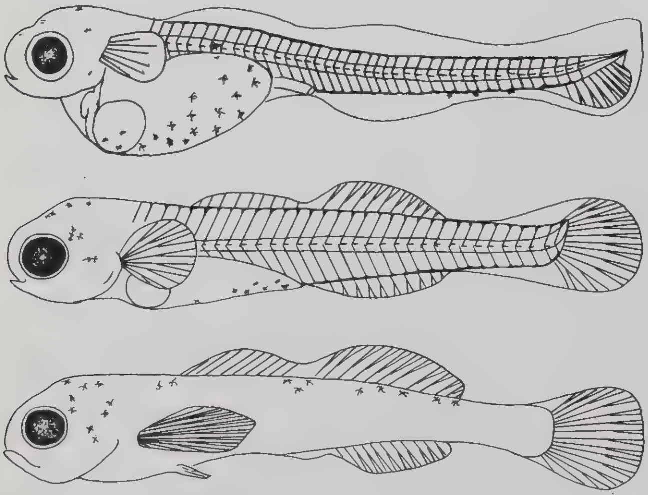

Fig. 7.—Top: *Etheostoma smithi* hatchling (6.7 mm total length). Middle: 3-day-old larva (7.3 mm total length). Bottom: 8-day-old juvenile (7.5 mm total length).

A series of 43 young *E. smithi* from 9 to 19 mm was collected in the study area on 21 July 1971. In those up to 10 mm long the color pattern was restricted to large dark spots on the dorsum and sides. At 15 mm the pattern was similar to that of adults but was more subdued. Larger individuals were darker.

At 9 mm scales were absent. At 10 mm scales were present only on the posterior half of the body. At 12 mm scales also were present on the anterior sides, and at 15 mm squamation was complete. The lateral line did not begin forming until an individual was about 18 mm, and the lateral line developed slowly after that; at 30 mm most individuals had only 4–6 pores.

E. smithi grew at a decreasing rate (Fig. 8). The relationship between standard length (Y) and age in months (X) expressed for males is $Y = 0.80 + 31.14 \log X$, with $r = 0.886$, and for females is $Y = 4.32 + 25.10 \log X$, with $r = 0.947$.

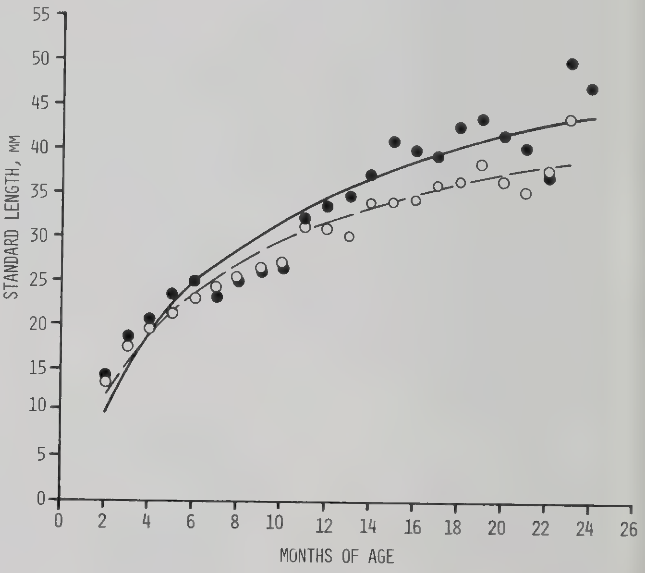

Fig. 8.—Size distribution by age of *Etheostoma smithi* collected in Ferguson Creek between 22 April 1971 and 19 June 1973. Black dots represent sample means for males; circles represent sample means for females. A total of 886 specimens is represented.

Males grew more rapidly than females (Fig. 8) and in their second year were significantly larger than females. At 13–18 months males averaged 39.3 mm and females averaged 34.3 mm ($t = 6.99$, df = 110). At 19–24 months males averaged 40.9 mm and females averaged 37.4 mm ($t = 3.16$, df = 49).

At 1 year (12 months) males (N = 29) averaged

33.3 mm and females (N = 39) averaged 30.9 mm. *E. smithi* reached one-half of the first year's mean length in approximately 13 weeks; this is about the same period as that estimated for *E. squamiceps* (12 weeks, Page 1974: 12) and *E. kennicotti* (16 weeks, Page 1975*a*: 9). The only 2-year-old (24 months) male was 47.1 mm; no 2-year-old females were found. The largest specimen examined from Ferguson Creek was a 50.1-mm, 23-month-old male collected on 22 April 1971.

DEMOGRAPHY

Density

On four separate dates at approximately 3-month intervals, quantitative samples of *E. smithi* were taken in Ferguson Creek by repeatedly seining an area until no more individuals were collected. The number collected was transposed into the number per square meter (Table 3).

TABLE 3.—Number of *Etheostoma smithi* per square meter collected in Ferguson Creek at approximately 3-month intervals, by habitat. Young were up to 1 year of age, adults over 1 year.

Collection Date	Number Collected	Number of *E. smithi* per Square Meter in		
		Slab Pools	Slab Riffles	Non-Slab Pools
		Adults		
8 July 1972	11	0.32	0	0.22
20 October 1972	6	1.61	0	0
17 January 1973	7	1.32	0	0
30 April 1973	0	0	0	0
MEAN		0.81	0	0.06
SD		0.77	...	0.11
		Young		
8 July 1972	128	0.11	0.19	13.33
20 October 1972	32	6.45	0	1.08
17 January 1973	43	1.36	0	0.62
30 April 1973	18	1.24	0	0.27
MEAN		2.29	0.05	3.83
SD		2.83	0.10	6.35

The highest densities of adults were in slab pools, the preferred habitat (Table 1). High densities of young were found in both slab pools and non-slab pools. The greatest density of *E. smithi* in Ferguson Creek, combining young and adults, was in the non-slab pools in July (13.6 per m^2).

Composition

Of the 886 *E. smithi* specimens collected in Ferguson Creek, 81.8 percent were up to 1 year of age, and the remaining 18.2 percent were over 1 year and up to 2 years of age (Table 4).

Females predominated in the young-of-the-year (−1) age class [1.2 females to 1.0 male ($\chi^2 = 4.80$; $P < 0.05$)] and in the 1+ year class [1.5 to 1.0 ($\chi^2 = 6.76$; $P < 0.01$)]. In the total sample (N = 886) the ratio was 1.2 females to 1.0 male ($\chi^2 = 9.55$; $P < 0.005$). Although significantly skewed in favor of females, the sex ratio in *E. smithi* was less skewed than in other *Catonotus* species studied (Page 1974: 13; 1975*a*: 10). It may be that the smaller size of *E. smithi* has resulted in less successful dominance by a small proportion of the male population, a larger proportion of successfully spawning males each year, and less pressure for selection toward a smaller ratio of males to females.

TABLE 4.—Distribution of sexes and year classes in samples of *Etheostoma smithi* collected in Ferguson Creek between 22 April 1971 and 19 June 1973.

Sex	Number by Year Class		Total
	−1	1+	
Male	333	64	397
Female	392	97	489
Total	*725*	*161*	*886*

Survival

Of the 397 males collected, 83.9 percent were in the −1 year class and 16.1 percent were in the 1+ year class. Assuming that each year class was collected in proportion to its relative number in the population, only 19.2 percent of the −1 year males survived to the second year. Of the 489 females, 80.2 percent were in the −1 year class and 19.8 percent were in the 1+ year class; 24.7 percent of the −1 year females survived to the second year. The survival of both sexes of −1 year *E. smithi* to a second year was 22.2 percent. These survival values were much lower than those of *E. kennicotti* in Big Creek (Page 1975*a*: 10) and *E. squamiceps* in Big Creek and somewhat lower than those of *E. squamiceps* in Ferguson Creek (Page 1974: 13–14). The oldest *E. smithi* from Ferguson Creek examined (assuming a May hatching) was a 24-month-old male collected in May 1973.

Migration

No migration was observed in the Ferguson Creek population of *E. smithi* during the study period. However, most spawning occurred in slab pools in the upper part of the stream system, and some upstream movements prior to spawning must have succeeded the downstream dispersal of the young.

Territoriality

Observations at Ferguson Creek and on aquarium-held *E. smithi* revealed much of the same type of territorial behavior observed for other *Catonotus* species. Males were strongly territorial, especially during the breeding season, and their territories were centered about depressions under slab stones. Territorial males were dark and had brightly colored fins, large-appearing eyes, prominent black vertical bars, and a bold black humeral spot. Territorial defense and combat were the same as those described for *E. kennicotti* (Page 1975*a*: 11).

Females became territorial, at least within the confines of an aquarium, but did not establish a territory centered about a stone. The female, defending only the immediate area around her, became boldly vertically banded, appeared to have enlarged eyes, and threatened invaders with lateral displays and nipping.

DIET

The stomach contents of 187 *E. smithi* were mostly immature insects and small crustaceans (Table 5). The food items most prevalent in all size classes were chironomids and ephemeropterans. Small darters also fed heavily on copepods, trichopterans, cladocerans, ostracods, and amphipods. Large darters fed more heavily than small darters on isopods and plecopterans.

A total of 13 taxa were found in the stomachs of *E. smithi*. This number represents fewer taxa than were found in *E. squamiceps* (16 taxa) collected in the same study area (Page 1974: 14–18) even though more specimens of *E. smithi* (187 versus 67) were examined. *E. squamiceps* attains a much larger maximum size (72 mm standard length in Ferguson Creek) than *E. smithi* (50 mm) and therefore presumably can ingest a greater variety of organisms.

Some seasonal variation in diet was evident among the 131 specimens of *E. smithi* ranging in length from 21 to 40 mm (Table 6). Trichopterans and ostracods were eaten mainly from September through December, plecopterans from December through February. Food consumption was heaviest from March through June.

INTERACTIONS WITH OTHER ORGANISMS

Competition

The life histories of the species of *Catonotus* studied have included a number of similar habits, including the occupation of slab-rock habitats and spawning on the undersides of slab stones, and it seems probable that competition among species of *Catonotus* occurs even to the point of competitive exclusion, as discussed by Page & Smith (1976). Potential competition between *E. smithi* (referred to as *E. obeyense*) and *E. squamiceps* in Ferguson Creek was briefly discussed by Page (1974: 18). Described species of *Catonotus* in the Cumberland River, in addition to *E. smithi* and *E. squamiceps*, are *E. obeyense, E. flabellare, E. virgatum,* and in the extreme upper region, *E. kennicotti.*

Predation

As potential predators three *Lepomis cyanellus* (178–187 mm) and four *Esox americanus* (62–78 mm) collected in Ferguson Creek were preserved and later examined. No *E. smithi* were found in the stomachs. No other information on predation on *E. smithi* has been published.

Parasitism

Except for one parasitic copepod *(Lernaea)* on a 19-mm female collected on 12 September 1972, no ecto- or endoparasites were found on *E. smithi* col-

TABLE 5.—Stomach contents of *Etheostoma smithi* from Ferguson Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred				Mean Number of Food Organisms per Stomach			
	<21 mm (34)	21–30 mm (69)	31–40 mm (62)	>40 mm (22)	<21 mm (34)	21–30 mm (69)	31–40 mm (62)	>40 mm (22)
Arachnida								
Acarina	2.9	...	...	...	0.03	...	...	...
Crustacea								
Cladocera	11.8	1.4	...	...	0.26	0.06	...	...
Ostracoda	8.8	2.9	3.2	...	0.18	0.04	0.03	...
Copepoda	44.1	5.8	4.8	4.5	1.53	0.19	0.08	0.05
Isopoda								
Asellidae	...	1.4	9.7	9.1	...	0.01	0.10	0.09
Amphipoda	8.8	5.8	8.1	4.5	0.09	0.06	0.10	0.14
Decapoda								
Cambaridae	...	...	1.6	...	...	...	0.02	...
Insecta								
Plecoptera	...	1.4	6.5	4.5	...	0.01	0.06	0.05
Ephemeroptera	38.2	47.8	50.0	40.9	0.50	0.59	0.58	0.73
Trichoptera	20.6	2.9	8.1	4.5	0.24	0.03	0.13	0.05
Coleoptera								
Dytiscidae	...	1.4	...	...	...	0.01	...	...
Diptera								
Chaoboridae	...	...	1.6	4.5	...	...	0.06	0.05
Chironomidae	76.5	72.5	66.1	54.5	3.53	3.72	4.45	1.86

Table 6.—Stomach contents of *Etheostoma smithi,* ranging in standard length from 21 to 40 mm, from Ferguson Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred												Mean Number of Food Organisms Per Stomach											
	Jan. (18)	Feb. (14)	Mar. (15)	Apr. (12)	May (11)	June (13)	July (4)	Aug. (4)	Sept. (9)	Oct. (9)	Nov. (10)	Dec. (12)	Jan. (18)	Feb. (14)	Mar. (15)	Apr. (12)	May (11)	June (13)	July (4)	Aug. (4)	Sept. (9)	Oct. (9)	Nov. (10)	Dec. (12)
Crustacea																								
Cladocera	...	...	...	...	...	...	...	...	...	...	...	8.3	...	...	...	...	...	...	...	...	...	...	...	0.17
Ostracoda	...	...	...	...	...	...	...	...	11.1	11.1	...	16.7	...	...	...	...	...	...	...	...	0.22	0.11	...	0.17
Copepoda	...	...	...	16.7	9.1	...	25.0	...	...	...	10.0	25.0	...	...	...	0.58	0.09	...	0.25	...	...	...	0.50	0.42
Isopoda																								
Asellidae	...	...	13.3	8.3	9.1	7.7	...	...	11.1	...	10.0	...	...	...	0.13	0.08	0.09	0.08	...	...	0.11	...	0.10	...
Amphipoda	...	7.1	26.7	...	9.1	7.7	...	...	...	11.1	...	...	...	0.07	0.27	...	0.18	0.08	...	...	...	0.11	...	...
Decapoda																								
Cambaridae	...	...	...	...	9.1	...	...	...	...	...	...	...	...	...	...	...	0.09	...	...	...	...	...	...	...
Insecta																								
Plecoptera	22.2	7.1	...	...	...	...	...	...	...	...	...	8.3	0.22	0.07	...	...	...	...	...	...	...	...	...	0.08
Ephemeroptera	50.0	28.6	53.3	8.3	36.4	53.8	75.0	50.0	33.3	77.8	90.0	58.3	0.72	0.29	0.67	0.08	0.73	0.69	0.75	0.50	0.44	0.78	1.00	0.67
Trichoptera	...	...	6.7	...	9.1	...	...	...	11.1	22.2	20.0	8.3	...	...	0.07	...	0.27	...	...	...	0.11	0.33	0.30	0.08
Coleoptera																								
Dytiscidae	...	...	...	...	...	7.7	...	...	...	...	...	...	...	...	...	...	...	0.08	...	...	...	...	...	...
Diptera																								
Chaoboridae	...	...	...	...	9.1	...	...	...	...	...	...	...	...	...	...	...	0.36	...	...	...	...	...	...	...
Chironomidae	77.8	92.9	86.7	83.3	81.8	61.5	50.0	75.0	55.6	55.6	40.0	41.7	2.67	4.79	6.13	6.00	10.09	5.54	0.75	1.75	1.22	2.11	1.40	1.67

TABLE 7.—Summary of life-history information on Ferguson Creek *Etheostoma smithi.*

Characteristic	Life-History Data
Principal habitat of adult	Slab pools
Principal habitat of young	Slab pools
Age at reaching sexual maturity	1 year
Age at first spawning	1 year
Size at reaching sexual maturity	Females about 30 mm; males about 35 mm
Sexual dimorphism	Adult males average larger, are more colorful, and have longer fins and a deeper caudal peduncle
Breeding tubercles	Absent
Number of mature ova counted	17–69
Description of egg in nest	2.2 mm in diameter, translucent, adhesive
Spawning period	From late April to mid-June
Spawning habitat	Slab pools
Spawning position	Both male and female inverted, usually head to tail
Nesting site	Underside of a slab stone
Number of eggs counted in nests	175–600
Egg guarding	Only by the male
Incubation periods	708–732 hours at 13°C, 300–324 hours at 21°C
Influence of sex on growth rate	By the second year males are significantly larger than females
Density	Up to 13.6 darters/m^2 in non-slab pools
Sex ratio among young	1.2 females : 1 male
Longevity	2 years
Maximum size	50 mm standard length
Migrations	No obvious patterns
Territoriality	Extreme in breeding males; strong in nonbreeding males; occasional in females
Principal diet	Aquatic insect immatures and crustaceans

lected in Ferguson Creek. No ectoparasites were found on *E. squamiceps* studied in the same area (Page 1974: 19–20), but a high infestation of spiny-headed worms *(Acanthocephalus)* was found. These worms were not found in *E. smithi.*

Hybridization

The only published account of hybridization involving *E. smithi* is the description by Page (1975*a*: 12) of successful matings between *E. kennicotti* and *E. smithi* (referred to as *E. obeyense*) in aquaria.

SUMMARY

The life-history information on *E. smithi* collected in Ferguson Creek between 22 April 1971 and 19 June 1973 is summarized in Table 7.

LITERATURE CITED

PAGE, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps,* in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———. 1975*a*. The life history of the stripetail darter, *Etheostoma kennicotti,* in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

———. 1975*b*. Relations among the darters of the subgenus *Catonotus* of *Etheostoma.* Copeia 1975 (4) : 782–784.

———, and M. E. BRAASCH. 1976. Systematic studies of darters of the subgenus *Catonotus* (Percidae), with the description of a new species from the lower Cumberland and Tennessee river systems. University of Kansas Museum of Natural History Occasional Papers 60. 18 p.

———, and P. W. SMITH. 1976. Variation and systematics of the stripetail darter, *Etheostoma kennicotti.* Copeia 1976 (3) : 532–541.

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SOME UNUSUAL NATURAL AREAS IN ILLINOIS

Robert A. Evers—Lawrence M. Page

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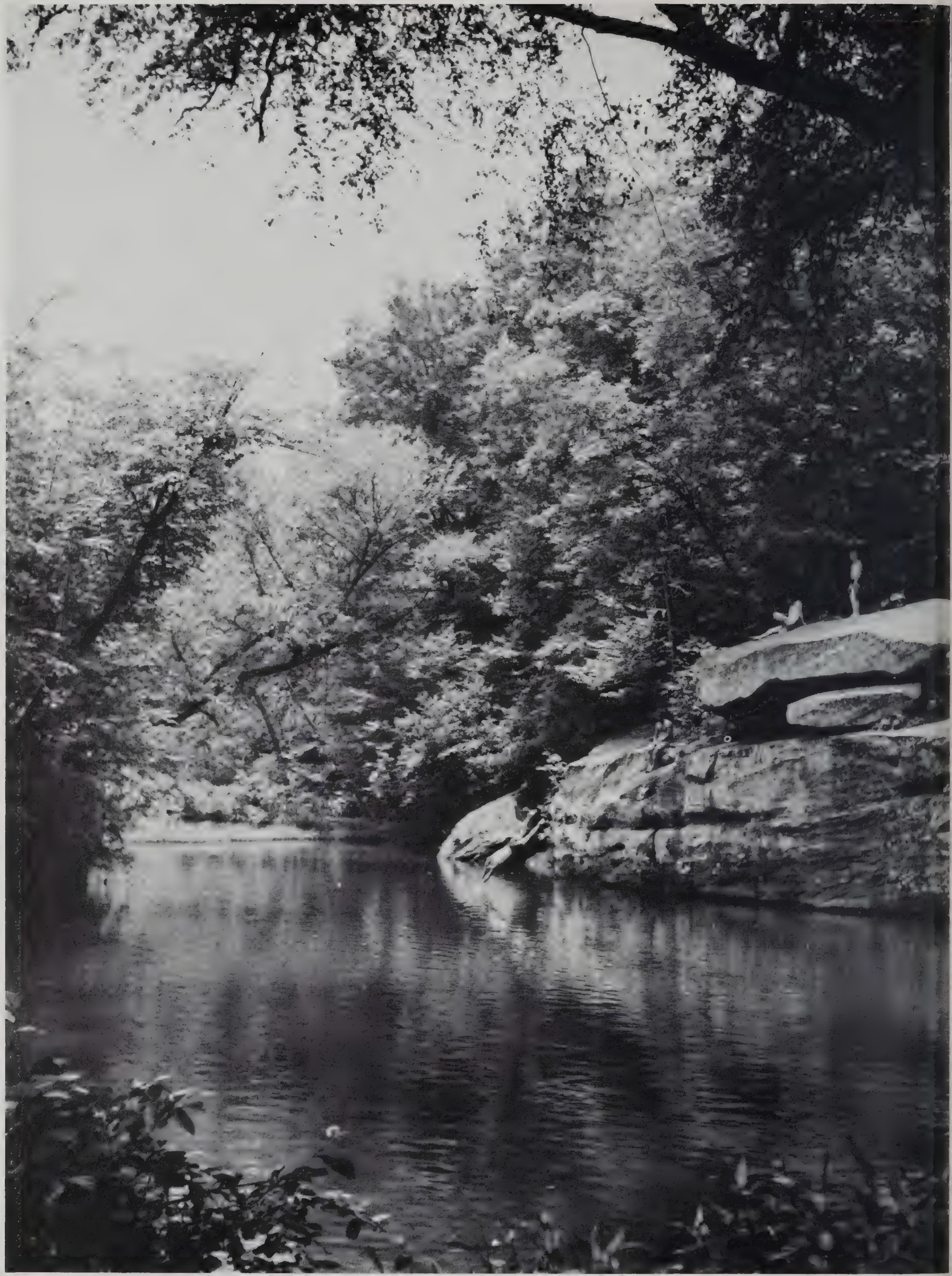

Fig. 1.—A quiet pool in Bay Creek as it flows through the Bell Smith Springs Recreational Area.

Some Unusual Natural Areas in Illinois

Robert A. Evers and Lawrence M. Page

This article has one main purpose: to acquaint interested persons with some unusual natural areas in Illinois. A natural area can be defined as an area of any size in which is found one or more rare species of plants or animals, an important biotic community, a significant natural landscape, or some prehistoric condition that has been scarcely, or not at all, disturbed by the activities of man. This definition permits the designation of certain localities in Illinois as natural areas although they may have been somewhat disturbed by man. Such areas can be called scientific areas as well as natural areas, because they are valuable for certain types of research.

Two centuries ago most of what is now Illinois was scarcely touched by man. By 1900, however, our state had lost much of its forest land and most of the once vast flatland prairie. The big game animals—buffalo, elk, cougar, and bear—could no longer be found in the state. The deer, beaver, and turkey were gone, but they have since been reintroduced. A small area east of Rantoul, Champaign County, was available as one of the last undisturbed flatland prairies of the state, but by 1915 it had been plowed. Illinois now has one sizable sample of flatland prairie—a part of the Goose Lake Nature Preserve—and remnants of varying sizes along railroads and fencerows. Not only the flatland, but other types of prairie have been destroyed. The large expanses of bottomland prairie, grasslands that occupied huge areas of the floodplains of our larger streams, have been plowed and cultivated. Only remnants, mostly along fencerows, remain. Most of the sand prairie has been converted into fields of grain or melons or transformed into Christmas-tree plantations or turkey farms. Prairies on the brow slopes of the valley walls of our large rivers—hill prairies—are the least disturbed of our prairies.

Our state and nation are experiencing a rapid rise in population and a concomitant need for more housing and homesites, more factory sites and shopping centers, and wider highways for swifter transportation. These place heavy demands upon land. As a consequence, many of our wetlands—swamps, marshes, and bogs—refuges for rare and unusual plants and homes or resting places of numerous birds, have been or are being drained. Hill prairies near metropolitan areas are being converted into homesites. Some of our remaining forest is being cut, and the land cultivated or used as homesites.

Although we are losing an important heritage—our natural areas—the rapidity of this loss has decelerated somewhat in the past few years.

In 1963 the General Assembly of the State of Illinois enacted legislation establishing an Illinois Nature Preserve System under the direction of the Illinois Nature Preserves Commission. The commission was organized in January 1964 and soon approved the south part of Illinois Beach State Park as the first natural area to become an official nature preserve in the system. Since that time many areas have been dedicated and more are being added to the system. Under the provisions of the law, any dedicated nature preserve cannot be removed from the system except by unanimous approval of the commission, the Director of the Illinois Department of Conservation, and the Governor of Illinois. Thus, natural areas have increased protection under this law if the areas are dedicated nature preserves.

Although natural or scientific areas are ordinarily places of beauty (Fig. 1), to the scientist they are much more than that. In such localities the biota—the community of plants and animals–lives in nearly undisturbed conditions. Here it is possible to study in natural surroundings a single species of plant or animal, or groups of plants or animals, or the relationships of both. It is in these places that the once abundant and now rare species can survive. In these refuges the biologist can study the soil flora and fauna and their relationships to other organisms, a field of study in which much remains to be done. Without these natural areas, protected from all types of "management," such research is impossible. To scientists and laymen natural or scientific areas are of great importance.

It is our hope that because of this report many citizens of Illinois will become conscious of the existence of our remaining natural areas and will obtain some knowledge of them. It is our further hope that this report may arouse a desire in some persons to visit these places, not to pick the flowers or kill the wildlife, but to enjoy the genuine natural beauty. (If a natural area is privately owned, permission to enter it should be obtained from the owner.) Many of us who are concerned about these areas hope that a sizable group of people will become interested and will help in the preservation of some

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This paper is printed by authority of the State of Illinois, IRS Ch. 127, Par. 58.12 Dr. Robert A. Evers, until his retirement in March 1976, was Botanist, Section of Botany and Plant Pathology, and Dr. Lawrence M. Page is an Associate Taxonomist, Section of Faunistic Surveys and Insect Identification, Illinois Natural History Survey.

Cover Photograph.—The bluff northwest of Prairie du Rocher. Red cedar and prairie herbs occupy the brow slope.

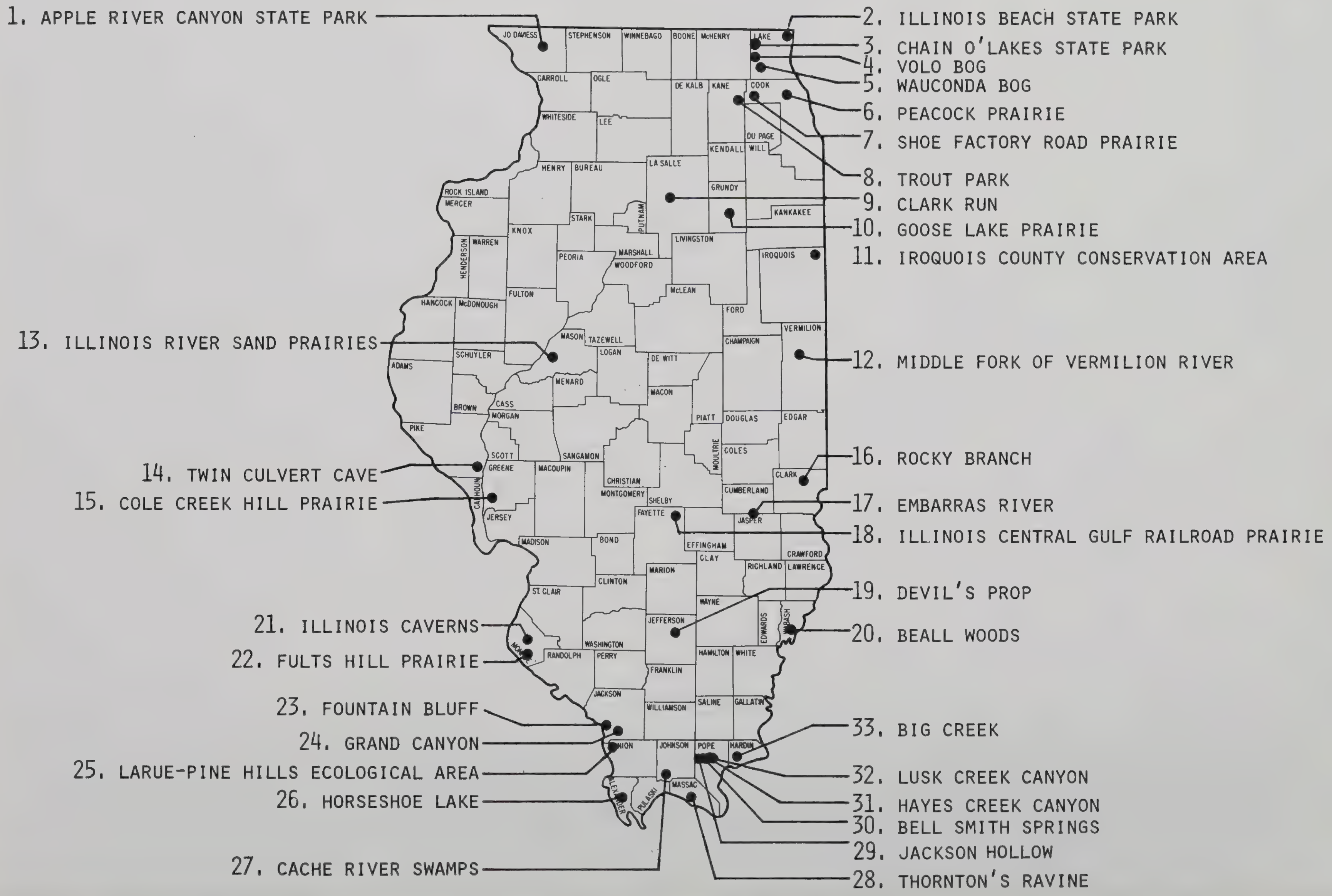

Fig. 2.—Map of Illinois showing locations of natural or scientific areas described in this report.

or all of these localities by supporting organizations that promote the preservation of natural areas and by supporting legislation that makes adequate preservation possible. We hope that Illinois citizens of the present and future generations may enjoy natural and scientific areas in their state.

The areas described in this report (Fig. 2) are not all of the nature preserves in the Illinois Nature Preserve System nor all of the areas owned or controlled by The Nature Conservancy or by other public or private institutions. For this report we have selected some of the natural areas described in a previous publication by Evers (1963); others are areas not described in that report but which have been or may be dedicated as nature preserves in the system.

Not included in the 1963 report but included here is information on the animal life in these areas. Information on the following groups of animals is mainly from the sources listed here: amphibians and reptiles, Smith (1961); fishes, Smith (1965 and 1971); mayflies, Burks (1953); leafhoppers, DeLong (1948); stoneflies, Frison (1935 and 1942); grasshoppers, Hebard (1934); pseudoscorpions, Hoff (1949); plant lice, Hottes & Frison (1931); butterflies, Irwin & Downey (1973); plant bugs, Knight (1941); caddisflies, Ross (1944); mosquitoes, Ross & Horsfall (1965); thrips, Stannard (1968); scorpionflies, Webb, Penny, & Marlin (1975); molluscs, Baker (1922 and 1939) and Parmalee (1967).

Information on the plants in these areas is mostly from the field notes and observations of the senior author as well as from five of his published reports (Evers 1950, 1951, 1955, 1961, and 1963). Other sources are cited in the text.

Common names are employed throughout this report except for plants and animals that have no recognized common names. Lists of the scientific equivalents for the common names are appended.

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I. APPLE RIVER CANYON

Apple River Canyon, about 4 miles southeast of the village of Apple River, is partly included in a state park that lies in the south half of section 4, T. 28 N., R. 4 E., in Jo Daviess County. The canyon extends beyond the park limits into the northwest quarter of section 9, the east half of section 8, the north half of section 17, and the south half of the northeast quarter of section 18. The actual area of the park is small; much more of the canyon should be purchased and preserved.

Geologically this is a most interesting locality. The valley that trends from northwest to southeast widens southeastward. Another valley, which joins the first at a right angle and trends southwestward, is narrow and has high cliffs. Younger than the valley that trends southeastward, it is the valley through which Apple River flows from this area, not into it, as would be the usual condition.

Before the Illinoian glaciation, Apple River flowed from the northwest to the southeast and possibly continued to the east through a valley now partly occupied by Yellow Creek in Stephenson County. Such a flow would readily explain the wider valley to the southeast. The Illinoian ice front blocked the southeast outlet and impounded the water. The impounded water cut a new channel to the southwest. This channel drained the valley from the northwest and also drained the blocked valley to the southeast. Upon deglaciation, Apple River continued to use this channel to flow southwestward and to empty into the Mississippi River.

The canyon is in a driftless area, one of the unglaciated parts of Illinois. The rocks exposed along the canyon walls are Ordovician in age, about 400 million years old.

Apple River Canyon has a vegetation of deciduous forest with northern coniferous representatives, prairie remnants, and an interesting cliff flora. Among the coniferous representatives are white pine and Canada yew. The forest contains such deciduous trees as white oak, northern red oak, Hill's oak, basswood, hop hornbeam, and rock elm. Prairie is represented mostly by remnants along the roadsides near the park and by a few remnants of the dry prairie type on the ridges. Big bluestem, little bluestem, Indian grass, and sunflowers are reminders of a more widespread prairie. The rare bird's-eye primrose grows on some of the cliffs (Fig. 3). One cliff is so much adorned by this plant that it is known as "Primrose Cliff" (Pepoon 1917). This rare plant also grows on cliffs farther upstream

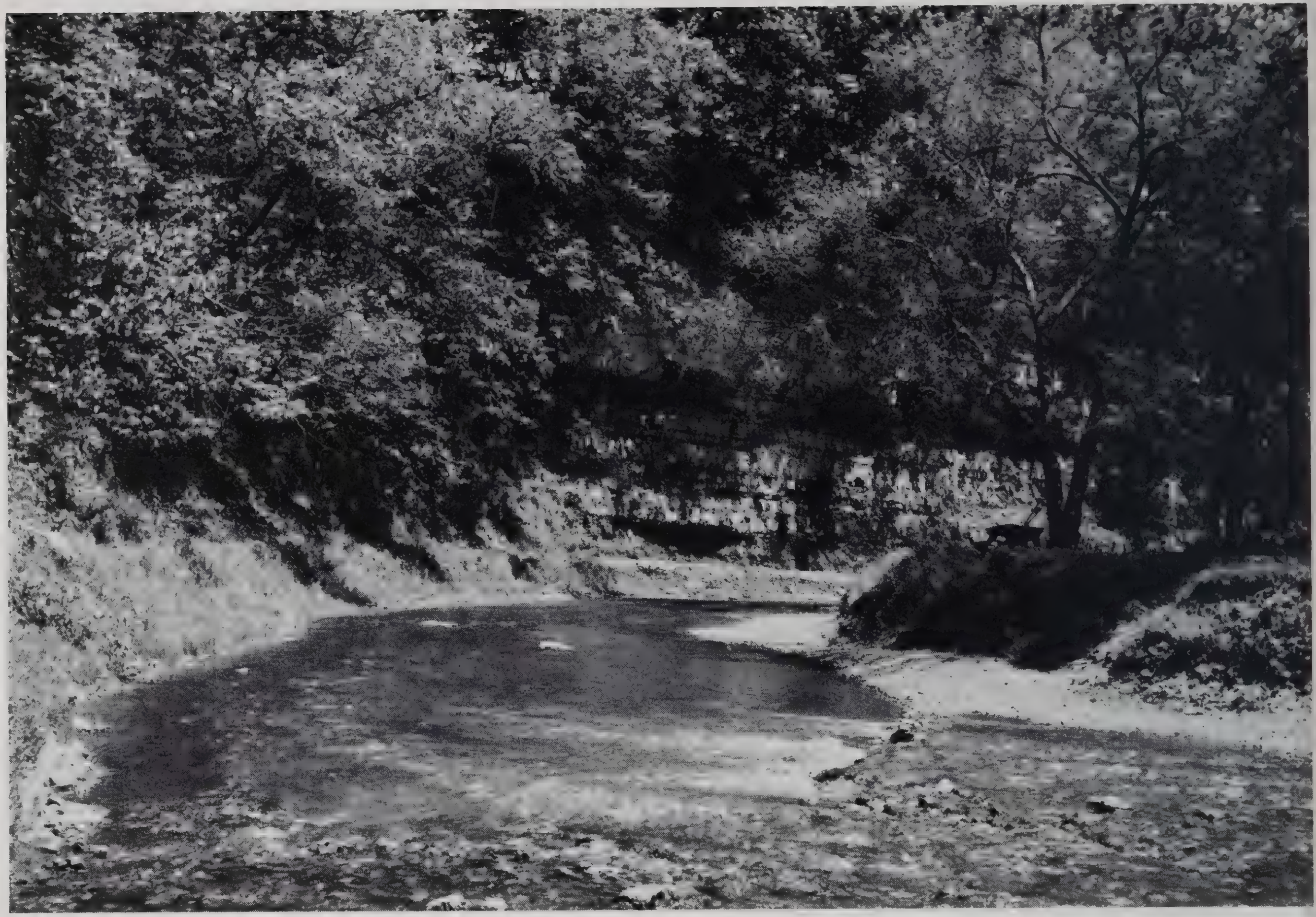

Fig. 3.—Apple River and the Primrose Cliff in Apple River Canyon State Park, Jo Daviess County. In early May the cliff is bedecked with many pinkish blossoms of bird's-eye primrose.

outside the park boundary. Studies of the plant life have been published by Boewe, Barrick, & Hague (1935) and by Fuller (1946), as well as by Pepoon. One of the bluffs in the canyon is of special interest, as it is one of the few nesting sites of the cliff swallow (Fig. 4) in Illinois (Graber, Graber, & Kirk 1972: 25).

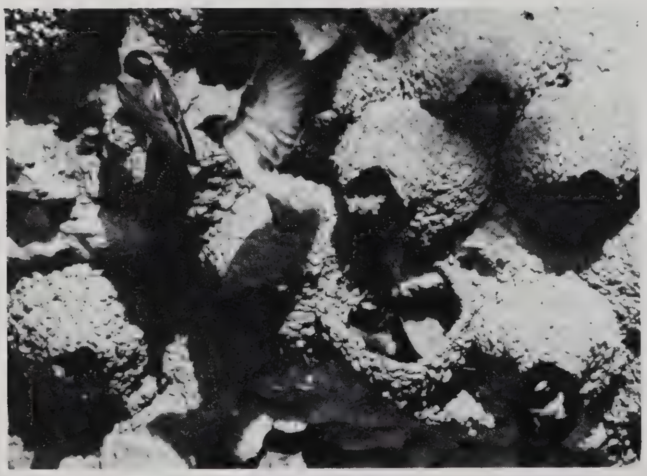

Fig. 4.—Cliff swallow colony on the Apple River in Jo Daviess County.

Although siltation and barnyard pollution are evident in Apple River, the river was rated good to excellent by Smith (1971:4), who cited as one of the most unusual animals in the area the Ozark minnow, a species mainly limited in distribution to streams of the Ozark Mountains. Another vertebrate found in the canyon and of rare occurrence elsewhere in Illinois is the timber rattlesnake.

Among the unusual invertebrates are several rare caddisflies, including *Leucotrichia pictipes,* recorded from nowhere else in Illinois, and the leafhopper, *Polyamia dilata,* known in Illinois only from this area.

Disturbance by visitors in the park is present but not yet acute. Some pressure on the facilities provided in this park has been removed by the opening of another park—Lake Le-Aqua-Na—to the east in Stephenson County. Picnicking and camping are permitted at Apple River.

Apple River Canyon State Park was acquired by the state in part through the persistent efforts of Dr. Herman Pepoon, a physician who preferred teaching high school biology to practicing medicine. His interest in nature doubtless developed during his youth, spent in the Apple River area. He visualized a much larger park (Pepoon 1920). Perhaps we can hope that more, if not all, of the canyon can be placed in public ownership.

2. ILLINOIS BEACH STATE PARK

Bordering Lake Michigan between Waukegan, Illinois, and Kenosha, Wisconsin, is a sand and gravel beach that is superimposed upon glacial till; its western limit is the Glenwood beach ridge of glacial Lake Chicago. Many writers have referred to this area as "the Waukegan moorland," but Gates (1912), who studied it in detail, called it the "Beach area."

Illinois Beach State Park occupies more than 1,600 acres of this marsh and sand terrace with dune ridges. The southern boundary of the park is approximately the middle of section 10, T. 45 N., R. 12 E. The eastern boundary is Lake Michigan, along which the park extends northward for 3.5 miles to the north line of section 26, T. 36 N., R. 12 E. The northern boundary follows the north line of sections 26 and 27 westward almost to the railroad trackway. The western boundary is irregular. The Illinois Beach Nature Preserve occupies over 700 acres from the southern boundary of the park northward to the old access road and the state park lodge and from the western boundary east to Lake Michigan.

The geologic history of the area is complex. It includes a glacial lake known as Lake Chicago in the Lake Michigan basin. The highest level of this lake, termed the Glenwood stage, was 640 feet above sea level. Subsequent stages, the Calumet and Tolleston, were at respective levels of 620 and 600 feet above sea level. Beaches were developed at all of these levels. The continued lowering of the lake to the present level (580 feet, mean level) resulted in the accumulation of the broad sand terrace of beach and dune ridges. The ridges of sand that border Lake Michigan were formed by currents that moved southward not quite parallel to the present shore. Wind has reworked some of the sand deposits, but no dunes of the magnitude of those on the east shore of Lake Michigan have been formed in the Beach area, because few strong and sustained winds come from the east, the wind direction required for dune building in this locality.

The plant cover of the Illinois Beach Nature Preserve includes deciduous forest, prairie, marsh, a man-made coniferous forest, and the aquatic vegetation of Dead River.

The deciduous forest is represented on the dune ridges, where black oak is dominant. White oak, bur oak, cottonwood, and quaking aspen also are present. The shrubs include lead plant, New Jersey tea, and poison ivy. Humus is not abundant in this forest.

The dune prairie is the typical sand prairie, with such grasses as little bluestem, switchgrass, Indian grass, and *Calamovilfa longifolia* var. *magna* among the common species. In the sand prairie, especially in blowouts, as well as in the forest, the creeping juniper and bearberry are abundant. These two species help to stabilize the sand. Wet prairie includes such grasses as prairie cordgrass, blue-joint, and sedges of the genus *Carex*. Fringed gentians flower in some of the wet prairies. Cattails are abundant in the marshland, where bulrushes also thrive.

Dead River, a sluggish stream, drains part of this area. Its source is a few small lakes in the marshland near the railroad trackway. The stream meanders northeastward, turns southward and southeastward, and makes an abrupt turn to the north and then to the east to enter Lake Michigan. The mouth of the river is often blocked by a bar (Fig. 5). In the water of Dead River can be found pondweeds, water-milfoil, and waterweeds. Elsewhere along the stream can be seen yellow pond lily and white water lily, pickerel weed, and giant bur-reed. White buttercup and common arrowhead also grow here.

The man-made coniferous forest is unique in Illinois. About a century ago Robert Douglass, a nurseryman, scattered seeds of various species of pines on the prairie-covered ridges south of the mouth of Dead River. The seeds germinated and the pines grew. Presently some species are thriving and seeding themselves. The Austrian pine is the most abundant of them, followed by Scotch pine (Fig. 6).

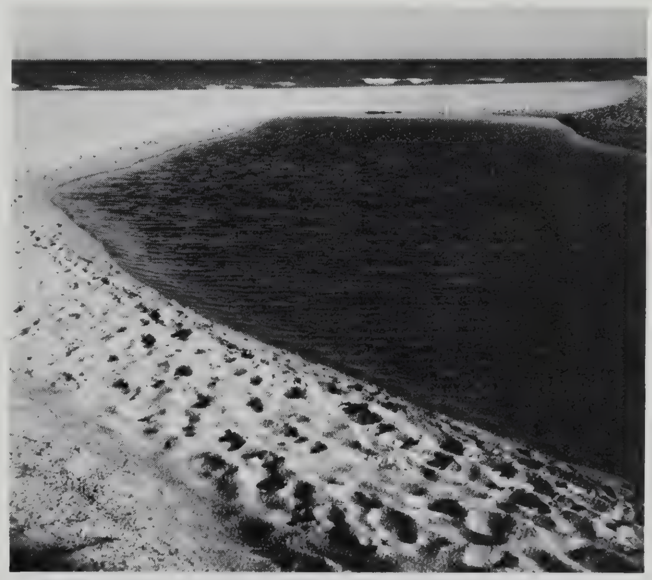

Fig. 5.—The mouth of Dead River in Illinois Beach State Park. The sand and gravel bar blocks the passage of water from the river into Lake Michigan.

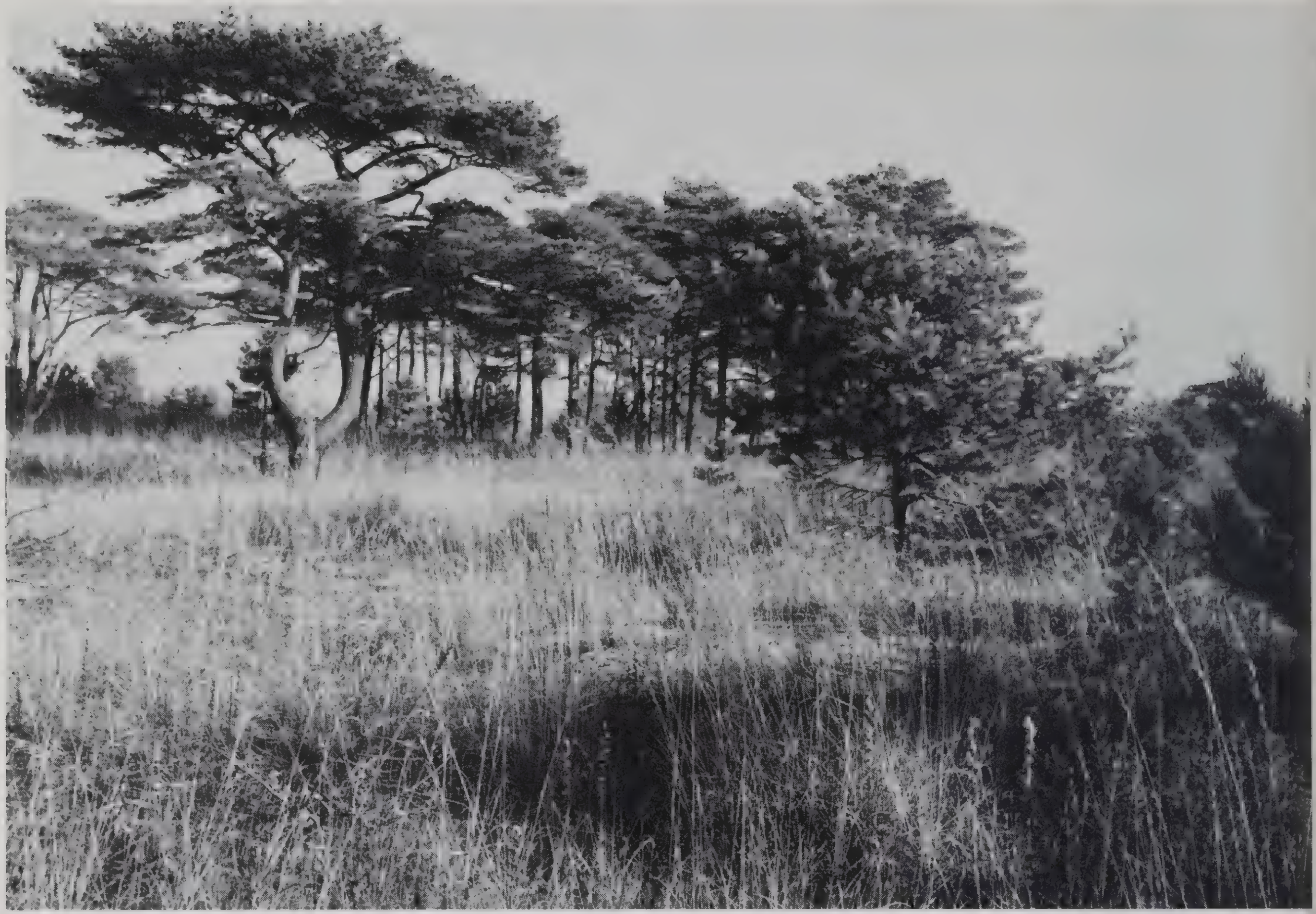

Fig. 6.—Some of the Scotch and Austrian pines that form a part of the coniferous forest south of Dead River in Illinois Beach State Park. Prairie plants dominate the herbaceous layer.

Several white pines survive on the western limits of this forest, and a few pitch pines are scattered in the sand just south of Dead River. A few trees of European larch grow in the interdunal troughs. Many prairie herbs still persist under the pines.

Along the shore of Lake Michigan are a few interesting associations. Beyond the range of the ordinary storm waves, sea-rocket and cocklebur are the dominant species; winged pigweed also grows here, and Russian thistle is an invading species but is not present every year. Arrowgrasses grow on the margins of beach pools.

The abundant animal life of the area includes many common species as well as some that are rare in Illinois. Ornithologists have observed more than 150 birds that use this preserve either as a breeding ground or as a temporary residence. Among the birds using the area as a haven during migration, and otherwise rarely seen in Illinois, are the knot and ruddy turnstone. The piping plover is a summer resident at the park, possibly nesting there.

The park borders the least disturbed Illinois portion of Lake Michigan and provides habitats for species of fishes absent or rare elsewhere in Illinois, including the lake chub, longnose dace, spottail shiner, lake chubsucker, smelt, ninespine stickleback, and slimy sculpin.

Entomologists have found the insect life of the area to be among the most interesting and unusual in Illinois. Ross (1944:11) described the area as having "one of the most extraordinary communities of caddis flies in Illinois" and cited *Fabria inornata, Triaenodes baris,* and *Polycentropus remotus* as particularly notable species. The park is the only recorded Illinois locality for the plant bug, *Plagiognathus syrticolae,* and for the pseudoscorpion, *Paisochelifer callus.* Other rare insects found in the area are the boreal thrips, *Anaphothrips cameroni*; the grasshopper, *Trimerotropis maritima,* and the leafhopper, *Texananus cumulatus.* Known from nowhere else in Illinois, the butterfly, *Callophrys polios,* is abundant at Illinois Beach.

Shelford (1911*a, b,* and *c*) made his classic studies on ecological succession in this area, and Ross (1963) analyzed the biota of the dunesland region in relation to Pleistocene glaciation.

Illinois Beach State Park is owned by the State of Illinois and is under the control and supervision of the State Park Division of the Department of Conservation. To accommodate the vast throngs of people who descend upon this place of beauty, a number of bathhouses have been constructed along the lake shore for those who wish to swim, and a lodge offers rooms and meals as well as an indoor swimming pool. The camping area has facilities for those who prefer that type of lodging, and numerous tables provide places for picnics. All of these lie north of the nature preserve. A museum or interpretation center is south of the lodge, and several paths direct the visitor through sand prairie and oak forest along Dead River.

Vandalism is still a problem at Illinois Beach, but let us hope that everyone soon will learn what a priceless heritage we have there.

3. CHAIN O'LAKES STATE PARK

Chain O'Lakes State Park and Conservation Area, located in T. 46 N., R. 9 E., Lake County, includes over 1,600 acres of disturbed oak woodland on gravel moraine, wet to moderately moist prairie, wet alkaline meadows, fens and cattail marshes, as well as several small natural glacial lakes that have not been altered appreciably.

The vegetation of the nature preserve is rich in species, and some, such as the beaked spike rush, tufted bulrush, pitcher plant, twig rush, and grass of Parnassus, are rare or uncommon in Illinois. Doubtless further search of the area will reveal other unusual plant species.

The pugnose shiner, blackchin shiner, banded killifish, brown bullhead, and Iowa darter are among the unusual fishes found in the glacial lakes.

The area is one of the few in Illinois where black terns and long billed marsh wrens can be observed. Ross (1944:10–11) discussed the uniqueness of the caddisfly community in the lakes, and Hottes & Frison (1931:156) recorded the rare plant louse, *Cinara laricis,* from the area.

The area is owned by the Illinois Department of Conservation.

4. VOLO BOG

Volo Bog, 1.5 miles north and 1 mile west of Volo, Lake County, is situated in the center of section 28, T. 45 N., R. 9 E. The bog is a water-laid peat deposit in two basins of a single depression that in earlier times formed a sizable lake on a glacial moraine. The bed is sand. The shallow basin is completely filled; the deeper basin has a pool of open water (Fig. 7). Above the sand is a jellylike ooze, and above the ooze is a deposit of sedge and sphagnum peat. Live sphagnum is growing on the surface. The depth of the peat varies; in the deeper basin it is 33 feet deep. Artist (1936) made a study of the peat, and Reichle (1969) described the vegetational associations in this bog. Sheviak & Haney (1973) made a detailed study of the vegetation patterns.

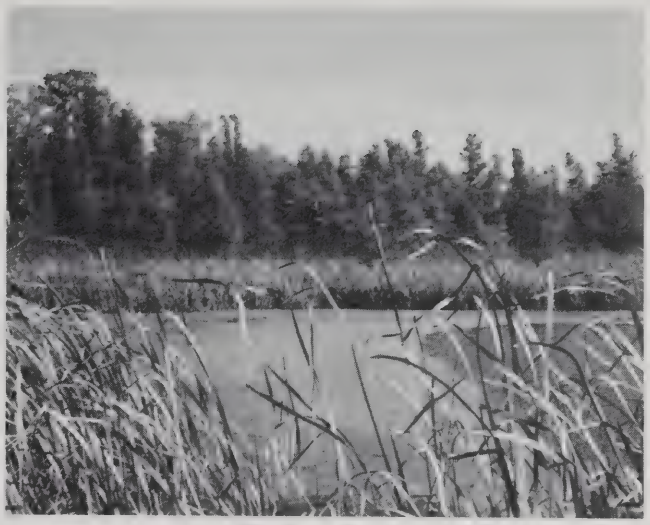

Fig. 7.—The pool of open water in Volo Bog, Lake County. Duckweeds grow on the surface of the water. The pool is lined with cattails.

Surrounding the bog is a zone that contains canary reed grass, smartweed, and Canada thistle. A few willows, such as black willow and peach-leaved willow, grow scattered in the narrow border of the bog and in the adjacent fields. The bog is easily viewed from the higher ground of the pastureland on the west. A plank walk (Fig. 8) extends from the pasture to the open pool within the bog.

Within the narrow border is a zone of shrubs in which poison sumac and winterberry are very abundant. Such herbs as sensitive fern, cinnamon fern, and marsh fern grow in the muck of the bog surface. To venture away from the plank walk is very

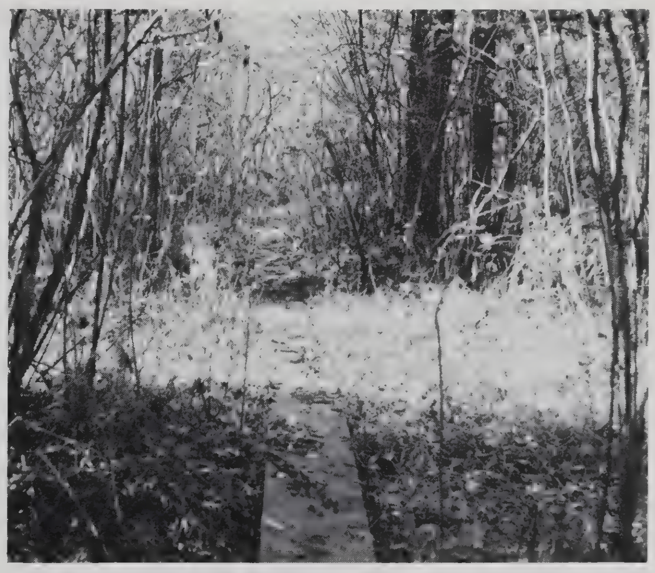

Fig. 8.—The plank walk near the entrance of Volo Bog. This walk permits easy access to the pool shown in Fig. 7.

hazardous, as it is possible to sink deep into the muck in those places where the plant roots grow sparsely beneath the surface and do not form a dense, tight network. Farther along the plank walk tamaracks tower above the shrubs. Near the open pool the density of the shrubs and trees decreases and herbaceous vegetation predominates.

The pool supports a heavy growth of several species of duckweeds. A zone of cattails with some giant bur-reed scattered throughout lines the shore of this pool. Numerous sedges and some bulrushes grow inland from the cattail zone. Some plants that are rare or semirare in Illinois occur in this zone. They include *Scheuchzeria palustris* var. *americana,* cotton sedge, *Dulichium arundinaceum, Pogonia ophioglossioides,* and the grass-pink orchid. An uncommon shrub in Illinois that thrives here is leatherleaf.

Inland from the pool and about 20 feet from the plank walk, the rare pitcher plant was once abundant. Far too many unscrupulous collectors have visited Volo and have almost destroyed the stands. Buckbean and purple cinquefoil were associated with the pitcher plant.

Reichle (1969), in his studies of the bog-inhabiting pselaphid beetles, reported 13 species of this group occurring in Volo Bog. Other insects whose occurrence at Volo Bog is significant because of their extreme rarity in Illinois are the thrips, *Thrips tripartitus*; the mosquitoes, *Wyeomyia smithi, Aedes abserratus,* and *A. punctor*; and the plant bugs, *Deraeocoris laricicola* and *Pilophorus uhleri.* A mouse tick, *Ixodes muris,* rare in museum collections, is known from Illinois on the basis of a specimen taken in this region. The central mudminnow, an acid-tolerating fish, occurs in this bog but is not restricted to the bog habitat in Illinois.

Part of Volo Bog, about 47 acres, was owned by the University of Illinois. In 1970 ownership was transferred to the Illinois Department of Conservation, and the site was dedicated as a nature preserve in the Illinois system. To preserve it in its natural state, the purchase of the remainder of the bog as well as some adjacent land is desirable. To this end, all of Wilson Bog and a portion of Brandenberg Bog, both lying to the northwest, have been purchased by the Conservation Department.

Volo Bog is a well-used educational and scientific area. Many students from the University of Illinois, Northwestern University, and other universities and colleges annually visit this bog to study ecology.

5. WAUCONDA BOG

Wauconda Bog, at the southeast boundary of the village of Wauconda, is in the north half of section 36, T. 44 N., R. 9 E., Lake County. The bog covers about 67 acres.

Like Volo Bog, Wauconda Bog was once part of a large lake of which Bang's Lake is but a small remnant. If the water level of Bang's Lake should rise 8 feet, the surface of Wauconda Bog would be covered with water. Unlike Volo, no pool of open water exists within the bog; the old lake bed is filled with sphagnum and sedge peat. In the cycle of development of bogs, Wauconda is an older bog than Volo.

Wauconda can be characterized as a bog with cattails, low shrubs, and herbs alternating with tamarack, tall shrubs, stunted deciduous trees, and an herbaceous understory (Fig. 9). A large stand of

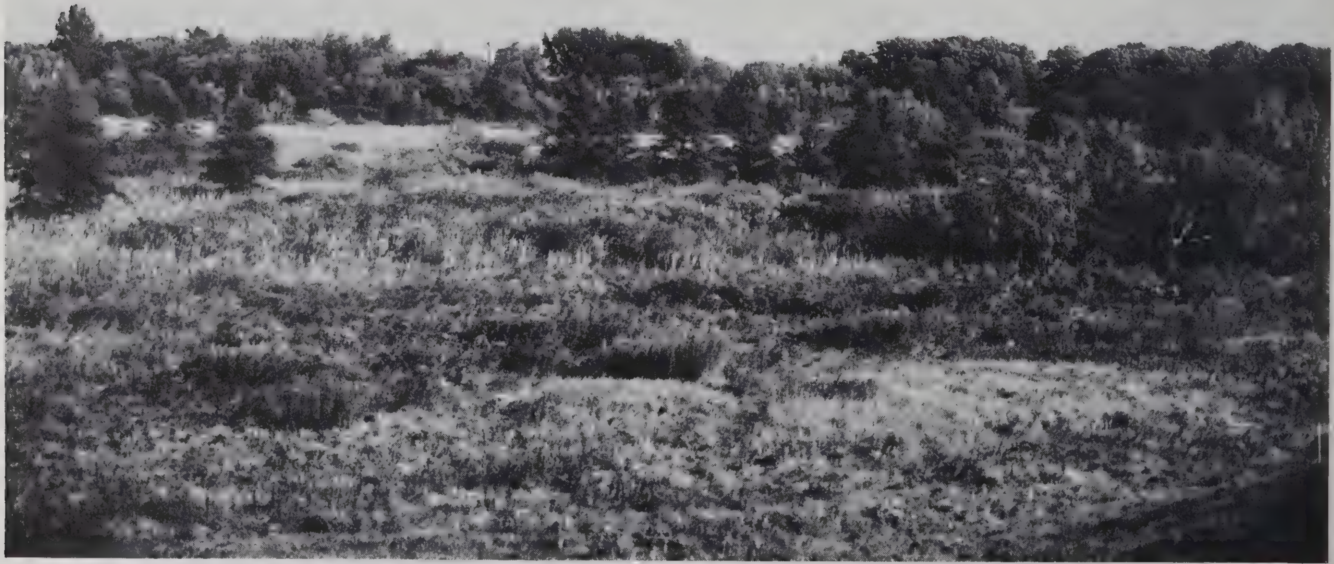

Fig. 9.—Wauconda Bog, Lake County. At the right are shrubs and small trees. In the middle distance are a few tamaracks. A large expanse of blue-joint is visible in front of the trees on the far side of the bog.

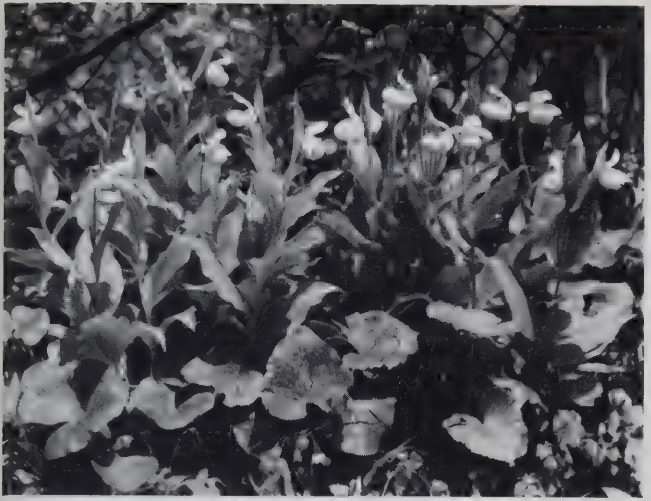

Fig. 10.—Pink ladyslipper, one of the rare plants of Wauconda Bog.

common reed grows near the center of the bog. Some of the tall shrubs are poison sumac, alder buckthorn, red osier, and winterberry. Some of the smaller shrubs are chokeberry, dwarf birch, and a number of species of shrubby willows. Deciduous angiospermous trees include soft maple, bur oak, quaking aspen, and basswood. Numerous sedges and grasses, among them blue-joint, form much of the herbaceous cover. Growing among the grasses and sedges are other herbs, a few of which are marsh marigold, purple cinquefoil, buckbean, swamp thistle, saxifrage, and numerous asters and goldenrods. The beautiful pink ladyslipper (Fig. 10) also grows here. Hummocks of sphagnum moss grow throughout, but not so abundantly as in Volo Bog.

Faunistically, Wauconda and Volo bogs are similar.

Most of Wauconda Bog will soon be ringed by residential areas. The pastureland that once bordered the bog on the south has recently been subdivided into lots and roadways. The north side of the bog touches the village. Part of Wauconda Bog was owned by the University of Illinois. In 1970 ownership was transferred to the Illinois Department of Conservation, and like Volo, Wauconda became a nature preserve in the Illinois system.

6. PEACOCK PRAIRIE

Peacock Prairie is a small prairie, only 4 or 5 acres, of the flatland type, located north of the intersection of Greenwood Road and Milwaukee Avenue, and south of Central Road in Maine Township, Cook County. The prairie is an example of the mesic black soil type which Vestal (1914) described from a stand east of Elmhurst on the Cook–Du Page county line. That stand has since been destroyed by urban expansion and interstate highway construction, and Peacock Prairie is one of the few remnants of this type of prairie in Illinois.

Peacock Prairie is trapezoidal in shape, bounded by homesites on the north and commercial enterprises on the south. As far as is known, it has never been seriously disturbed by plow, overgrazing, fire, or bulldozer. It has been trampled in the past by children's play activities, but this apparently had little adverse effect. Although it is small, it is rich in plant species. Paintin (1929) described this prairie, recorded the plants found in it, and attempted to quantify the data. Forty years later Betz & Cole (1969) made a comparative study to determine changes that had occurred during that period and recorded approximately 130 established plant species.

The preservation of this site can be credited to the determined efforts of a small group of citizens, especially a number of devoted women, such as Mrs. F. T. Popelka, Mrs. Olof Dahlskog, and Mrs. J. Wayne Cole. Their many hours of work were finally crowned with success. Peacock Prairie was purchased, saved from destruction, and set aside as a nature preserve. It is presently under the supervision of the University of Illinois at Chicago Circle.

7. SHOE FACTORY ROAD PRAIRIE

Shoe Factory Road Prairie is a rare remnant of prairie vegetation growing on a kame, a hillock of stratified glacial drift. It is located in the northwest quarter of the northwest quarter of section 10, T. 41 N., R. 9 E., about 2 miles north-northwest of Streamwood, Cook County. It lies between Illinois Highway 59 (Sutton Road) and the Elgin, Joliet, and Eastern Railroad on the south side of Shoe Factory Road, from which the natural area takes its name.

A sandy gravel forms the surficial deposit of the kame, and in one place it has been mined, leaving a depression or pit in the moderately steep south-facing slope. From the summit, which lies along the north boundary of the preserve, a steep slope descends to the road and doubtless was formed by man when the road was constructed through a small part of the kame. Eastward and westward from the summit the slopes appear little disturbed and are not so steep as are brow slopes of most bluffs of larger streams in Illinois.

Prairie vegetation covers about 8 acres of the south-, southwest-, and west-facing slopes of the hillock. Needlegrass and little bluestem are common; Indian grass, prairie dropseed, and side-oats grama also grow here. Canada bluegrass appears to be limited to the disturbed places, such as in the pit or near the road. In spring the prairie shows scattered yellow blossoms of star-grass, puccoon, and lousewort. The purple and the white prairie clovers, the bluish flowers of the many-flowered scurfpea, the white of rattlesnake master and flowering spurge are present in summer. In autumn the white and blue flower heads of several species of asters and the yellow of the goldenrods add color to the greenish backdrop of grasses. The east-facing slope has forest species, some of which, hazel and box elder, have invaded the prairie.

The presence of side-oats grama, the abundance of little bluestem, and the occurrence of many-flowered scurfpea are reminiscent of the hill or bluff prairies along the western border of Illinois. The presence of the three species of blazing stars and the three species of silphiums, namely compass plant, rosin weed, and prairie dock, together with rattlesnake master and downy gentian remind the observer of prairie wetter than hill prairie but not as wet as the floodplain type. Such a combination of prairie species and the absence of similar prairies in the vicinity make Shoe Factory Road Prairie so unusual and so valuable.

One of the most unusual animals of this prairie is the rare thrips, *Illinothrips rossi.*

Shoe Factory Road Prairie is owned by the Forest Preserve District of Cook County, which also serves as custodian. Through the efforts of a Conservation Director of the district, the late Cap Sauers, a wise and energetic conservationist, this prairie was purchased by the district and, to insure its protection, placed in the Illinois system, where it became the Shoe Factory Road Nature Preserve. The district is to be commended, not only for preserving this unusual prairie, but also for placing in the Illinois Nature Preserve System nearly 4,000 acres of its holdings in Cook County. Some of these are examples of forest types, one contains sand prairie, one a glacial bog, and others preserve marshland and wet prairie. This action is an example of a local governmental agency, a county forest preserve district, setting aside natural areas within its holding as nature preserves in the Illinois system. To some biologists the Forest Preserve District of Cook County is one of the wonders of the modern world. This action certainly strengthened that belief.

8. TROUT PARK (ELGIN BOTANICAL GARDEN)

Trout Park, also called Elgin Botanical Garden, is located in the northeast quarter of section 1, T. 41 N., R. 8 E., on the east bluffs of the Fox River in the northern part of Elgin, Kane County. The tract now embraces less than 60 acres; formerly it was larger.

"Trout Park is not a 'park' in the ordinarily accepted sense of the term. It is more than a park; it is a preserve—a last refuge for the plant and animal life of an extensive region in these morainic hills of northern Illinois known as the 'Oak Openings' or Oak Grove Savannas because of their prevailing timber character." So wrote H. C. Benke (1932*a*) in the Elgin *Courier-News* for March 29.

Numerous springs and seeps occur on the east bluffs, which are composed of glacial drift. The water from the springs and seeps, forming pools and brooks, makes its way downslope to the base of the bluffs and into the Fox River. These water sources apparently never run dry. The bluffs support a mesic vegetation—plants that grow in habitats that are neither extremely wet nor extremely dry. Along the rivulets and bordering the seeps, arbor vitae grows abundantly (Fig. 11). According to Benke, some individuals of this species in Trout Park are older than our nation. Willows of various species, elderberry, and touch-me-not abound in these moist situations.

The forested ravine slopes of the east bluffs support such trees as butternut, quaking aspen, large-toothed aspen, northern red oak, hackberry, blue ash, and elm. The bluff-top forest includes white oak, northern red oak, white ash, and wild black cherry.

The alternate-leaved dogwood is one of the understory trees. Numerous shrubs grow under the forest canopy. Witch hazel, several shrubby dogwoods, and viburnums are common. Trout Park is rich in an herbaceous flora that includes many species in numerous genera and families. Over 60 species of grasses thrive here. Of rare plants in the Illinois flora, this refuge boasts of six orchids and five gentians, including the bottle or closed gentian and the fringed gentian. Benke (1932*a* and *b*) included in his *Courier-News* articles published on consecutive days three lists of the plants in Trout Park and neighboring areas.

The unusual vertebrates of Trout Park are the mottled sculpin and the brook stickleback, both of which occur in the spring-fed rivulets.

Ross (1944:8) discussed the unusual caddisfly community in the Elgin Botanical Garden, citing seven species not found elsewhere in Illinois. Other unusual insects are a rare mayfly, *Baetis vagans*; two rare stoneflies, *Leuctra tenuis* and *Nemoura trispinosa*; and two rare butterflies, the swamp metalmark, *Calephelis muticum,* and Harris' checkerspot, *Chlosyne harrisii.*

On March 29 Benke (1932*a*) wrote: "While owned by the City of Elgin, the park tract is under the custody of those who so earnestly labored for its acquisition—the nature societies of Elgin, foremost among which are the Illinois Nature Study, and the Elgin Audubon Societies. These establish the rules for the park's supervision which are in turn executed by the city. This admirable arrangement guarantees the tract's preservation with nature supreme and artificialities restricted to the minimum."

Unfortunately, preservation of the tract was not guaranteed. The Illinois Toll Road, Interstate 90, now passes through what was the largest and biologically richest ravine in Trout Park. The right-of-way is about 450 feet in width and stretches in

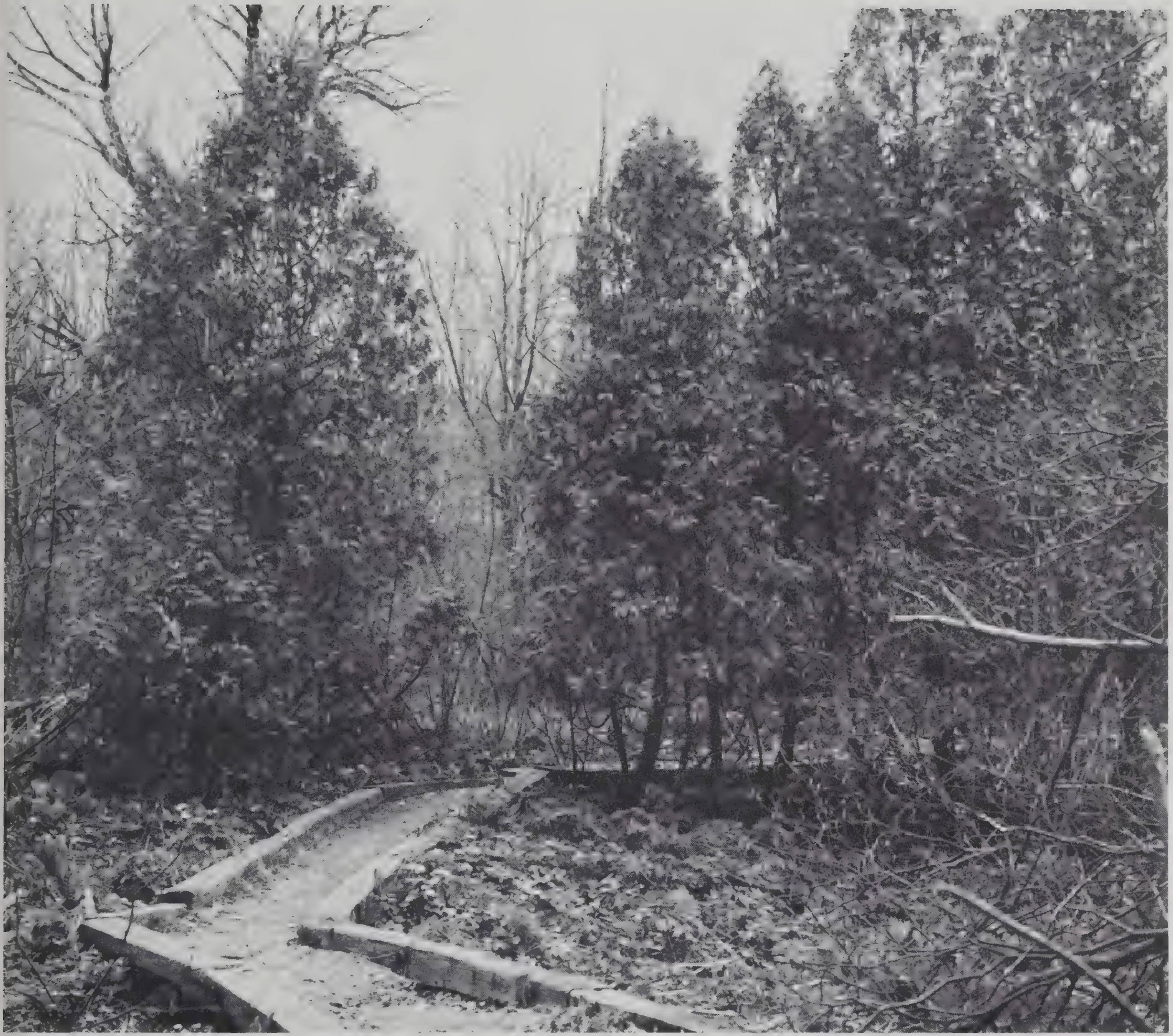

Fig. 11.—A path on the bluffs at Trout Park, north of Elgin, Kane County. The path leads the visitor past large arbor vitae trees, some of which are visible in the photograph.

the park from the base of the bluff to the summit. The experience of Elgin proves that individuals, organizations, and local governments must be on the alert if they are to prevent the destruction of irreplaceable natural areas by "artificialities" that could be located elsewhere.

Presently, Trout Park is owned by the City of Elgin.

9. CLARK RUN

Clark Run is a small stream, about 7 miles long, northeast of Utica, La Salle County. The stream originates in section 31, T. 34 N., R. 3 E., and empties into the Illinois River near Utica. The area of biological importance lies in the extreme north part of section 9 and the southwest quarter of section 4, T. 33 N., R. 2 E., where the stream flows through a canyon, the walls of which are St. Peter sandstone.

The stream cascades over falls into a canyon (Fig. 12) and then slowly meanders between sandstone cliffs. Marshy areas border the stream in many places where the canyon cliffs have been eroded away. In these areas the skunk cabbage and marsh marigold flower in early spring. The latter occasionally blooms also in autumn. Bordering the stream are stands of blue beech, willows, and other small trees. Mayapples form sizable clones on the relatively dry parts of the floodplain. Canada yew, arbor vitae, red cedar, and white pine grow on the cliffs.

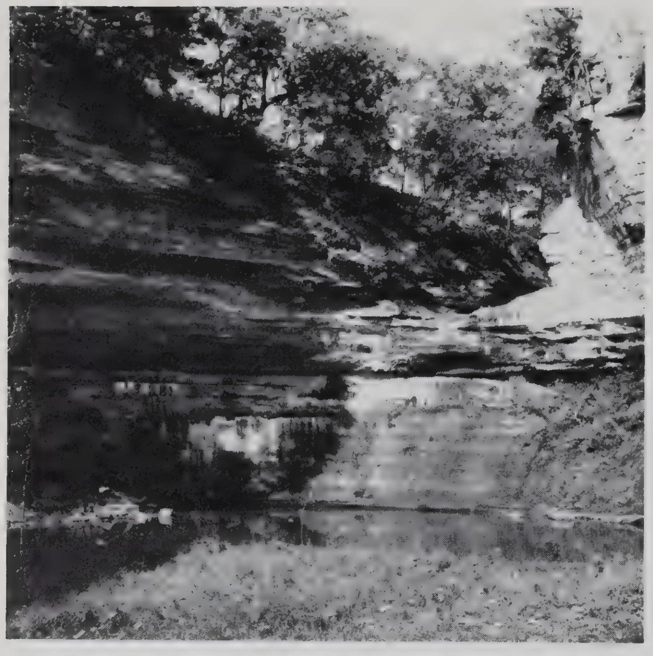

Fig. 12.—Upper part of the canyon at Clark Run. The stream enters the canyon by this route. Mallards were swimming on the water of the pool below the falls on October 11, 1962, the date this picture was taken.

In those places where the sandstone cliffs have eroded to leave steep slopes, rattlesnake plantain, partridge berry, bunchberry, white pine (some of the trees 24 inches in diameter), and other plants can be observed. Witch hazel, saxifrage, pasture gooseberry, and false lily-of-the-valley thrive in the ravines.

Above the cliffs the conditions are more xeric; that is, the water supply is lower and the evaporation rate higher. Black oak and Hill's oak find a favorable environment in such sites. Some of the shrubs of the xeric bluff tops are fragrant sumac, smooth sumac, and leadplant. Herbaceous plants include little bluestem, needlegrass, wild indigo, and the narrow-leaved aster.

In the leaf mold at Clark Run, a southern thrips, *Trachythrips watsoni,* reaches its northern limit. It apparently extends northward along the narrow confines of sand areas that border the Illinois River.

Clark Run, similar in many respects to some of the canyons of Starved Rock State Park, has not been overrun by people. Much of the canyon area and most of the adjacent uplands have been pastured, some parts severely. In spite of this treatment, some of the rare plants have survived. If cattle were removed, doubtless Clark Run would revert to a very beautiful and biologically rich area.

Clark Run is presently in private ownership.

10. GOOSE LAKE PRAIRIE AND MARSHES

Goose Lake prairie and marsh area lies north of the Lorenzo Road and south of the Illinois River, southeast of Morris and northwest of Lorenzo, and occupies all or parts of sections 3, 4, 9, and 10, T. 33 N., R. 8 E., and parts of section 34, T. 34 N., R. 8 E., in Grundy County. The area of the nature preserve is 1,513 acres. Thus, it is a sizable and valuable preserve.

A number of biotic communities are represented in this preserve. Tall-grass prairie, grassland with dominant grasses 5-8 or more feet tall, occupies portions of the area. In this type of prairie at Goose Lake, big bluestem is the dominant grass. Associated with it are Indian grass and switchgrass, as well as wild roses, sunflowers, and goldenrods. Midgrass prairie of grasses between 2 and 5 feet tall is represented by a large stand. Little bluestem and Indian grass are dominant. In dryer parts of the nature preserve Kentucky bluegrass has become dominant, possibly because cattle in years past concentrated on these sites. A disturbance community occupies those places which had been cultivated and since have been allowed to return to prairie. In such situations at Goose Lake switchgrass and Indian grass are common. In the wet prairie community, prairie cordgrass is dominant, but blue-joint is common. In the marsh community, river bulrush, great bulrush, cattail, and common reed dominate. The aquatic community is represented in the numerous bodies of open water, an outstanding feature of the area.

Campbell *et al.* (1970) compiled a list of 326 species of vascular plants that grow in this nature preserve. Zales (1971) listed 30 species of mosses and liverworts.

The ponds are shallow and muddy and support few aquatic vertebrates but offer nesting habitats for a number of unusual birds, including the American bittern, upland sandpiper, Henslow's sparrow, and marsh hawk (Birkenholz 1975). A butterfly occurring in Goose Lake Prairie but rare elsewhere in Illinois is the broad winged skipper, *Poanes viator*.

The purposes of this preserve are preservation of a native prairie community, education, and research. To carry out the second purpose, an interpretive center and a system of trails have been constructed in the preserve and the buffer zone to the west of the nature preserve. Prairie species are to be planted in the buffer zone used for educational purposes. When the interpretive center, trails, and observation towers are completed, Goose Lake Prairie and Marshes Preserve will be an outstanding preserve in the Illinois system.

Goose Lake area is owned by the Department of Conservation.

11. IROQUOIS COUNTY CONSERVATION AREA

Iroquois County Conservation Area lies in sections 22, 23, and 24, T. 29 N., R. 11 W., east-northeast of Beaverville, Iroquois County. This area of sand, clothed with black oak forest, prairie, marsh, and pools of open water, has about 2,000 acres.

Among the unusual plants in the forest and prairie are colicroot, white-bract hymenopappus, and nodding ladies'-tresses. Here are also habitats for outlier populations of reptiles normally more western in distribution, including the bullsnake, ornate box turtle, and six-lined racerunner.

In and near the conservation area, especially to the south, are small to medium-sized creeks with sandy bottoms, masses of submerged vegetation, and headwater marshes. These streams contain fishes peculiar to sand areas, including the ironcolor shiner and weed shiner, and other uncommon fishes, such as the blacknose shiner, the lake chubsucker, starhead topminnow, northern longear sunfish, and least darter. The major stream of the area is Beaver Creek, cited by Smith (1971) as a particularly notable stream with a rich assemblage of unusual species.

Owned by the state and managed by the Illinois Department of Conservation, the Iroquois County Conservation Area almost adjoins the Willow Slough Wildlife Refuge in Newton County, Indiana, considerably enhancing the area as a biological refuge. The area also provides suitable nesting habitat for the veery (Graber & Graber 1973), a rarity in Illinois.

12. MIDDLE FORK OF THE VERMILION RIVER

The Middle Fork (Fig. 13) of the Vermilion River between Potomac and the junction with the Salt Fork near Oakwood in Vermilion County is a high-gradient river with many boulder riffles, extensive raceways over both gravel and sand, and clear pools over sand or silt substrates. Many raceways are bordered by emergent vegetation, especially

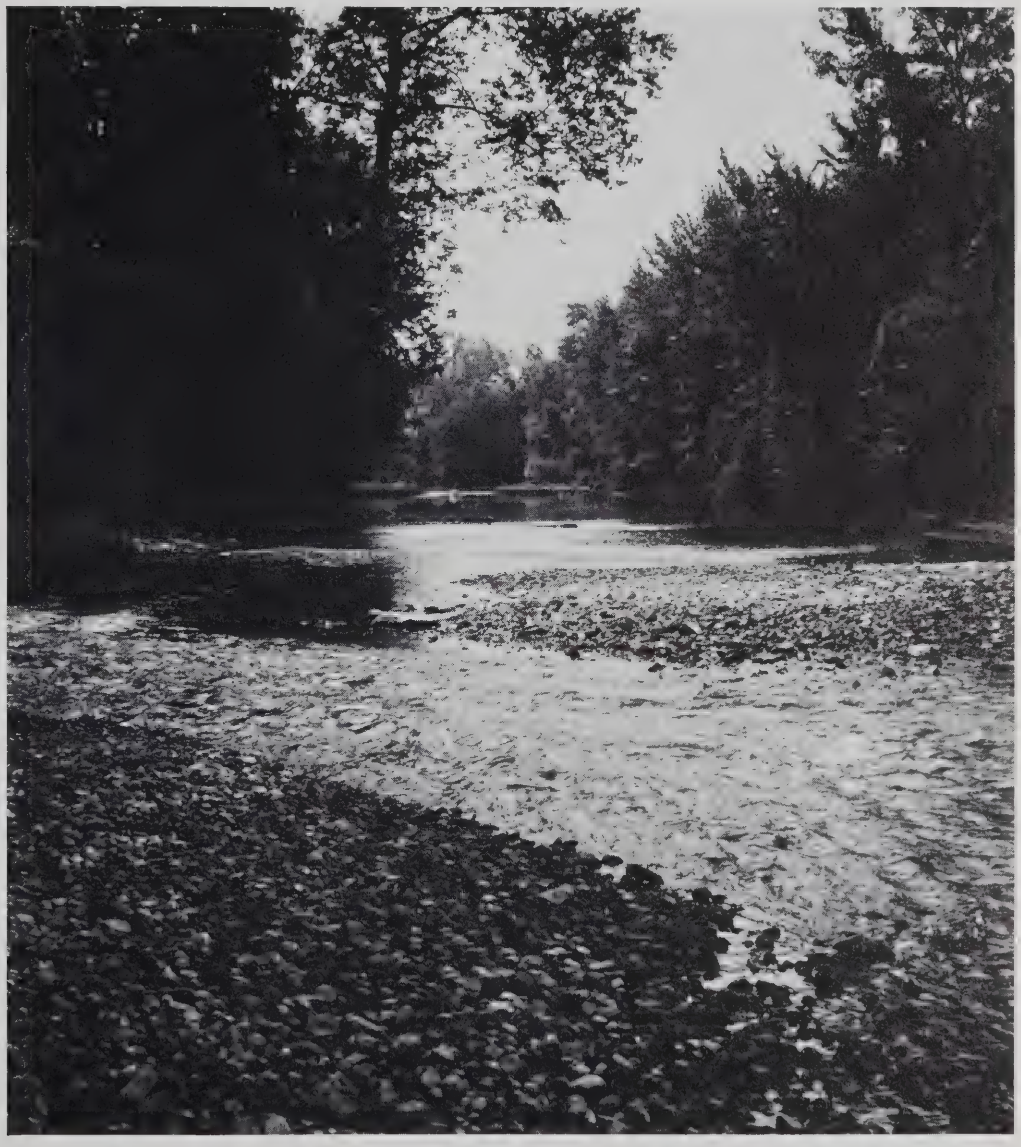

Fig. 13.—Middle Fork of the Vermilion River near Collison, Vermilion County. In addition to an extensive bed of gravel, the Middle Fork has boulder riffles and exposures of bedrock.

water-willow. The river has a large variety of aquatic animals that are very unusual in Illinois. Terrestrial habitats on the floodplain and on the slopes of the bluffs harbor a great diversity of plants and wildlife.

Several of the animals in the Middle Fork are highly indicative of clean, clear, gravel-bottom streams and denote the Middle Fork as a stream only minimally disturbed by human activities, an attribute rapidly becoming a rarity in Illinois. These Middle Fork inhabitants are the river redhorse; bigeye chub; silver redhorse; suckermouth minnow; mimic shiner; bluebreast darter; eastern sand darter; dusky darter; rainbow darter; greenside darter; smallmouth bass; the crayfish, *Orconectes propinquus*; and the caddisflies, *Hydropsyche frisoni* and *H. cheilonis.*

Among the fishes of the Middle Fork are four recognized as rare and endangered fishes of the midwestern states (Miller 1972): the bluebreast darter, bigeye chub, river redhorse, and mimic shiner. The first three of these fishes were also recognized by Lopinot & Smith (1973) in their list of rare and endangered fishes of Illinois. The bluebreast darter occurs in Illinois only in the Middle Fork.

Baker (1922) and Ross (1944) commented on the unusualness and diversity of the Middle Fork invertebrate fauna. In discussing the fauna of the Vermilion River system, Baker noted especially the great diversity of the molluscan fauna, having found 60 varieties of molluscs in his survey of the stream system. The mussel, *Lampsilis fasciola,* is restricted in Illinois to tributaries of the Vermilion River.

In addition to the uniqueness of the aquatic fauna, suitable terrestrial habitats exist along the Middle Fork to support a large diversity of wildlife, including 20 species of amphibians, 23 reptiles, 58 nesting birds, and about 37 mammals. For several species, including the red-backed salamander, queen snake, and ringneck snake, the Middle Fork environs form the periphery of their respective ranges, and they are able to use the area as a refuge from further range shrinkage. The rare and unusual salamander, *Ambystoma platineum,* occurs in Illinois only in wooded areas along the Middle Fork (Morris 1974). The southeastern shrew, recently found in the area, is extremely rare in Illinois. The lark sparrow, known to nest along the Middle Fork, is rarely found in eastern Illinois.

In section 8, T. 20 N., R. 12 W., 3.5 miles southeast of Collison, a unique prairie occupies the upper slopes of the west-southwest-facing gravel bluff. Seep springs occur at the bluff base bordering the Middle Fork. Locally the prairie is called Windfall. It is one of the few gravel bluff or gravel hill prairies in Illinois. In addition to the usual prairie grasses, many other prairie plants grow here. Some of these are Indian paint brush, blazing star, azure aster, and hill prairie ladies'-tresses. Grass of Parnassus, Riddell's goldenrod, and four-flowered loosestrife occur in the seeps.

The uniqueness of the Middle Fork was recently recognized in a publication of the Illinois Natural History Survey (Smith 1971) in which streams were classified on the basis of their fish diversity and in which the Middle Fork was described as "one of the finest in Illinois."

A considerable portion of the lower Middle Fork is included in Kickapoo State Park, the site of a former Indian village and, more recently, of abandoned strip mines. Here and farther upstream the relatively steep stream gradient, rocky riffles, deep pools, and wooded banks make the river attractive to canoeists, hikers, naturalists, and fishermen. The varying habitats support a number of important sport species, including smallmouth bass, spotted bass, rock bass, longear sunfish, channel catfish, and several species of suckers.

A proposed impoundment of the Middle Fork would inundate the best stretch of the river and eliminate much of its natural beauty and most of its unique biological characteristics, as discussed by Smith (1968). In contrast, an alternative plan, establishing the Middle Fork as a river corridor park, would maintain and protect the unique characteristics of the river.

13. ILLINOIS RIVER SAND PRAIRIES

Along the east side of the Illinois River from the big bend in Putnam County south into Scott County sizable deposits of sand form terraces upon which a dunic topography has developed. These deposits were laid down during the Wisconsinan glaciation. At that time the meltwater from the ice front with its load of sand and silt was flooding the valley of the Illinois and aggrading it. After the close of glaciation, the river cut its channel into these sand deposits, leaving the terraces. The sand terraces of the Illinois River valley supported forest, prairie, and marshland until the coming of European man. After his arrival, much of the area of sand terraces was put into cultivation—into fields of corn, wheat, soybeans, rye, melons, or into pine plantations or turkey farms. Scattered throughout the area are small remnants of forest and prairie.

The University of Illinois Foundation owned land on the sand terrace northwest of Kilbourne, Mason County. This tract, known as the Wilkinson Farm, as well as additional acreage to the north, was acquired by the Illinois Department of Conservation. Most of the acquisition was dedicated as a nature preserve in the Illinois system. This holding includes both prairie and forest.

The prairie lacks large dunes but possesses sizable blowouts of a compound nature. These blowouts tend to be stabilized by goat's rue (Fig. 14); three species of three-awn grass; the common panic grass of sand areas, *Panicum pseudopubescens*; and the sedge, *Bulbostylis capillaris.* Other sedges, *Cyperus schweinitzii* and *C. filiculmis,* grow scattered in the

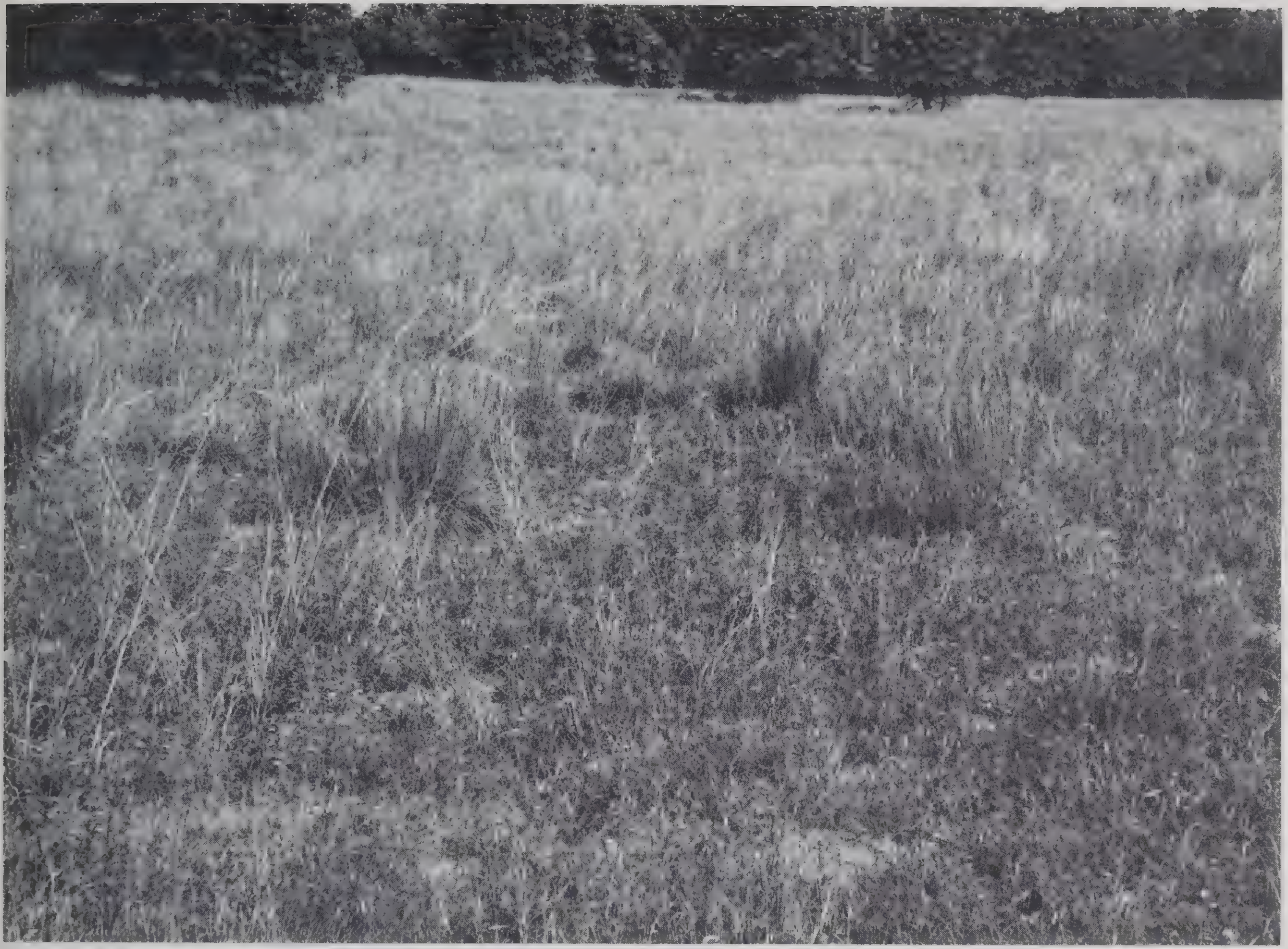

Fig. 14.—View of a sand prairie near Kilbourne, Mason County, showing a society of goat's rue. The black-jack oak and black oak forest in the distance is second growth.

blowouts. Black-jack oak thrives at the border of one blowout.

Elsewhere the sand prairie contains such grasses as little bluestem, switchgrass, sand love-grass, needlegrass, and the tall *Calamovilfa longifolia* var. *magna*. In the interstices are such plants as goat's rue, polygala, small to moderately large patches of prickly pear, and rose mallow. A common shrub of this prairie is fragrant sumac. In one depression where the sand remains quite moist, blackberries and seedbox thrive.

It is impossible to find all the plants of the Illinois River sand prairies growing in this one locality near Kilbourne. Within a 15-mile radius, in other prairie remnants, numerous other species can be found, including two plants rare in Illinois, *Cristatella jamesii* and bladder-pod, the latter growing in the Henry Allan Gleason Memorial Nature Preserve, north of Topeka, Mason County, an area dedicated in 1970.

Unusual vertebrates in the Illinois River sand prairies are the Illinois chorus frog and the Illinois mud turtle. Great Plains vertebrates, animals restricted in distribution in Illinois, that live in these sand prairies include the slender glass lizard, western hognose snake, and the bullsnake. Other vertebrates found here and notable for their rarity in Illinois are the spotted sunfish, ironcolor shiner, starhead topminnow, lake chubsucker, and lark sparrow. Graber, Graber, & Kirk (1974:10) recorded the western kingbird in this area but noted that it is not likely to be found with much regularity.

The rock pocketbook, a mussel rarely found in large populations, is locally abundant in the Illinois River in the sand prairies region. Insects of the area that never or rarely have been found elsewhere in Illinois are the thrips, *Anaphothrips nanus*; the mayfly, *Baetis anachis*; the caddisfly, *Lype diversa*; the grasshoppers, *Amphitornus coloradus* and *Mermiria neomexicana*; and a butterfly called the Ottoe skipper, *Hesperia ottoe*.

During the early part of this century a number of workers were occupied with studies of sand areas in Illinois. The work of Hart & Gleason (1907) is considered a biological classic. A study of the sand land vegetation by Gleason (1910) included the Illinois River sand areas. Vestal (1913) studied the relationships of plants and animals, especially the insects, in the sand areas of the Illinois River, chiefly those near Havana. Recently, Johnson (1970) made a study of the vegetation and the resident populations of mammals and birds of the Wilkinson Farm area.

14. TWIN CULVERT CAVE

Twin Culvert Cave is located in the middle of the southwest quarter of section 17, T. 7 S., R. 2 W., about 2 miles southwest of Pearl, Pike County. The name is taken from the two large limestone overpasses (Fig. 15) that span a small stream, the bed of which at this place also forms a part of the county road to the southeast. The overpass or culvert on the south carries tracks of the Illinois Central Gulf Railroad. The culvert on the north has become covered with brush. It was once part of a railroad trackway, now abandoned. The creek that flows through these culverts is small, but in periods of heavy rains it may rise 8 feet or more above the gravel stream bed. The cave is located between the two culverts, upslope on the west bank of the small stream, very close to the present railroad trackway.

The slope on which the cave is found supports a deciduous forest containing such species as hard maple, white ash, black walnut, chinquapin oak, hop hornbeam, and shingle oak growing together. Some of the common shrubs are poison ivy, wild hydrangea, bladdernut, wafer ash, and buckthorn. Wild grapes and climbing bittersweet are common vines. Of the herbaceous plants, fragile fern, clearweed, bedstraws, and violets occur frequently.

The bluff bordering the abandoned trackway on the west side of the creek has been altered by the removal of rock, possibly for the construction of the fill and the culverts. This disturbed site contains a mixture of native forest and prairie species, as well as some common weeds of European origin.

The chief objects of interest in this locality are the cave (Fig. 16) and springs. Bretz & Harris (1961) described the cave. "Entrance to this cave is through a roof breakdown. A network of joint-controlled vertical slots that should not be negotiated without a rope is immediately encountered. Two sets of joints cross at approximately right angles. Ceilings and depths appear to vary along each set." The cave is sometimes visited by a large colony of gray bats (Smith & Parmalee 1954:201), a migratory species that is rare and poorly known. Other unusual vertebrates in the vicinity of the cave are the banded sculpin, southern redbelly dace, and timber rattlesnake.

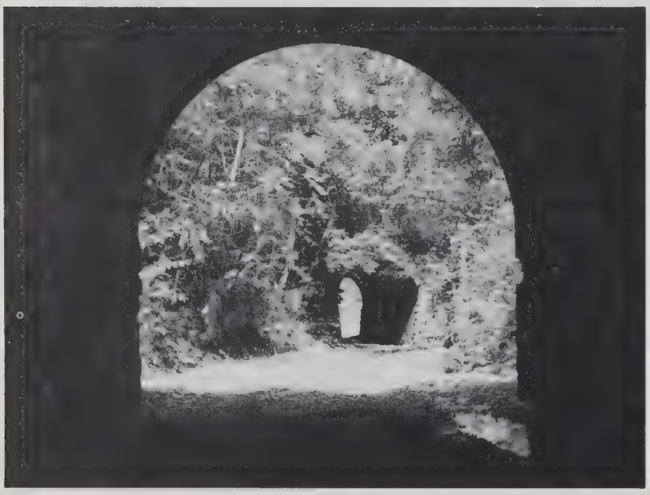

Fig. 15.—Culverts constructed of local limestone near Pearl, Pike County. These culverts supply the name—Twin Culvert Cave—for the nearby cave. An infrequently used county road and a small stream share the culverts.

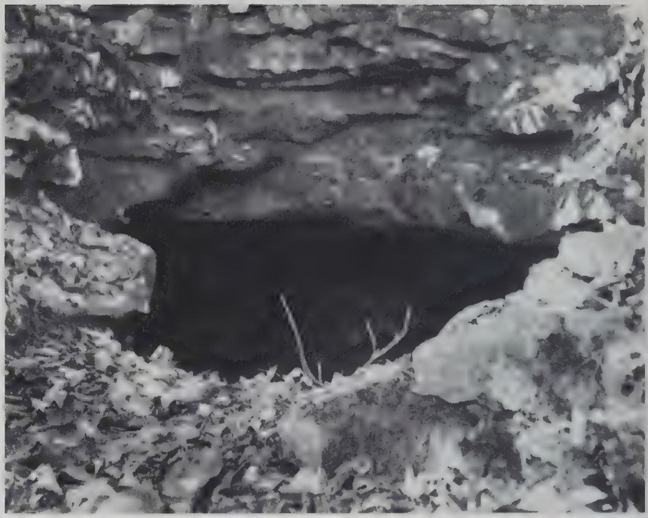

Fig. 16.—Entrance to Twin Culvert Cave. Because of the nature of this cave, ropes, ladders, and ample light should be available if its exploration is attempted.

Twin Culvert Cave is owned by The Nature Conservancy.

15. COLE CREEK HILL PRAIRIE

Cole Creek hill prairie is located in the northwest quarter of section 4, T. 9 N., R. 13 W., 2 miles south of Eldred, Greene County. The prairie occupies part

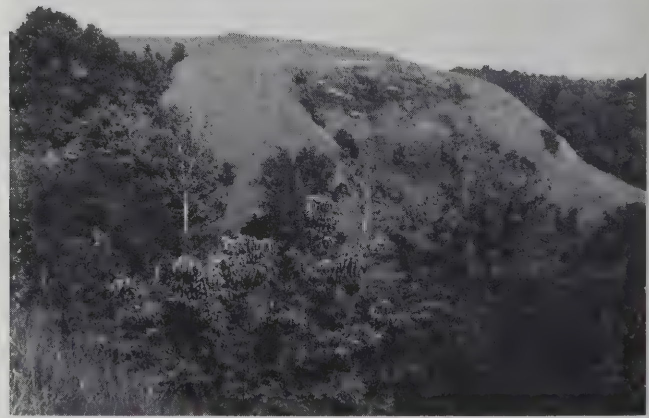

Fig. 17.—One of the spurs of the hill prairie along Cole Creek, south of Eldred, Greene County. Forest with many chinquapin oaks grows in the coves.

of a bluff of the Illinois River and part of the north bluffs of Cole Creek. This locality was previously described under the name South Eldred hill prairie (Evers 1955).

The bluff of the Illinois River has a small toe slope, a limestone cliff, and a loess-covered brow slope. The bluffs of Cole Creek also have a loess cover but few visible rock outcrops. The loess was deposited during Wisconsinan time.

Vegetation characteristic of hill prairies covers more than 4 acres of three southwest-facing slopes that extend downslope (Fig. 17). Little bluestem is the dominant grass. Some other grasses of these slopes are big bluestem, Indian grass, side-oats grama, and Scribner's panic grass. The bluets, *Houstonia nigricans,* grows in this prairie, which is near the northern limit of the range of the species in Illinois. On October 1, 1958, 29 stems of hill prairie ladies'-tresses (Fig. 18) were observed in this prairie.

This orchid appears well adapted for growth in hill prairie stands of pastured loess slopes. A few miles south of Cole Creek, at Dayton Hollow, 91 stems were counted on October 10, 1968. More astonishing, however, were the 275 stems found in pastured hill prairie on October 6, 1970, a little more than 4 miles north of Eldred.

The toe slope, the ravines, and the bluff tops support a deciduous forest in which common tree species are white ash, American elm, various oaks and hickories, red cedar, and Iowa crabapple. Some of the shrubs present are prickly ash and rough-leaved dogwood.

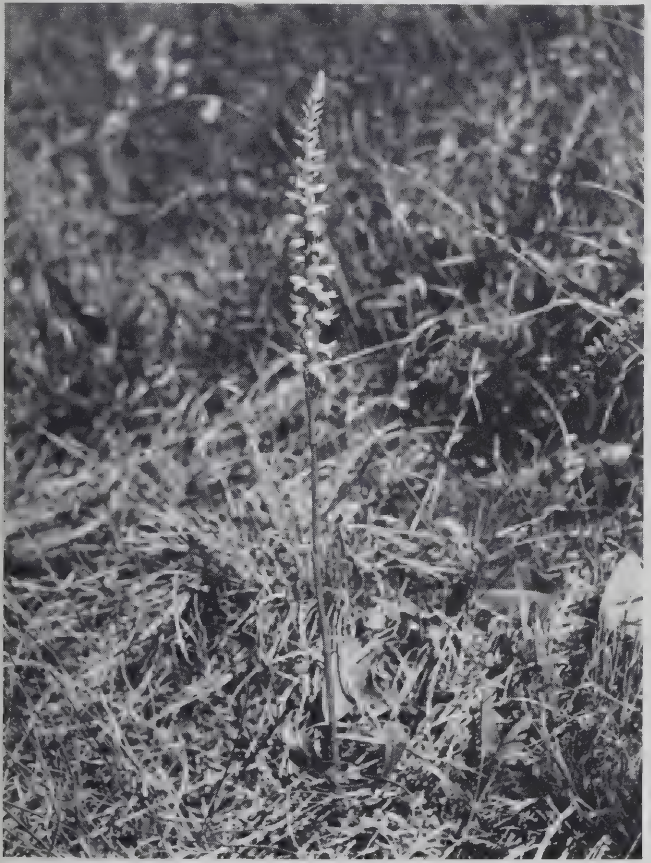

Fig. 18.—Hill prairie ladies'-tresses. In 1958, 29 stems of this species were observed in Cole Creek hill prairie.

Local residents report that they frequently observe white-tailed deer on these prairie slopes. In the vicinity is a relict colony of northern ringneck snakes, and both the western long-tailed salamander and glass lizard occur in the area. The westernmost record of the leaf beetle, *Brachycoryna melsheimeri,* is based upon a collection made here.

Cole Creek hill prairie is presently in private ownership.

16. ROCKY BRANCH

Rocky Branch is the name applied to a small stream in northern Clark County. This small stream, not more than 1.5 miles in length, has its source in the east half of section 30, T. 12 N., R. 12 W.; it empties into the West Fork of Big Creek in section 29 of the same township. The area of greatest interest to naturalists is more than 300 acres in extent. It centers on the small stream, on the surrounding forest, and on much of the forest on the south bank of Big Creek, including its tributary ravines. By road, the Rocky Branch natural area is 1.5 miles east and 1 mile north of Clarksville (known also as Dolson).

Rocky Branch has long been attractive to the lover of natural beauty (Stover 1930). The small stream has cut deeply into the sandstone to form a valley with steep walls and, in some places, perpendicular cliffs (Fig. 19). Sizable undercuts in many of the cliff bases clearly show the eroding power of the stream when in flood. During flood stage the water in Rocky Branch may rise 8 feet above its gravel and sandstone bed, as evidenced by the debris left in trees and shrubs along the bank. Several small tributary ravines enter Rocky Branch from the south. Their streams have carved beautiful gorges in the sandstone.

The vegetation of Rocky Branch is chiefly deciduous forest. In wide parts of the valley are small plots that were once cleared of trees, maintained for a while as cultivated fields, and later abandoned. The narrow road that once traversed the valley from its head to its mouth has also been abandoned. The forest of the ravine floor is rich in plant species. Trees of this forest include sycamore, hard maple, tulip tree, beech, butternut, white ash, and hackberry. Some of the understory trees and shrubs are blue beech, wild hydrangea, elderberry, bladdernut, and spicebush. The ravine floor is a place of beauty in the spring, when it is carpeted with numerous patches of colorful wild flowers. By autumn the forest floor is no longer a carpet of color, but here and there are asters, goldenrods, and white snakeroot. Among the plants of the forest floor are such ferns as the broad beech, Christmas, and grape.

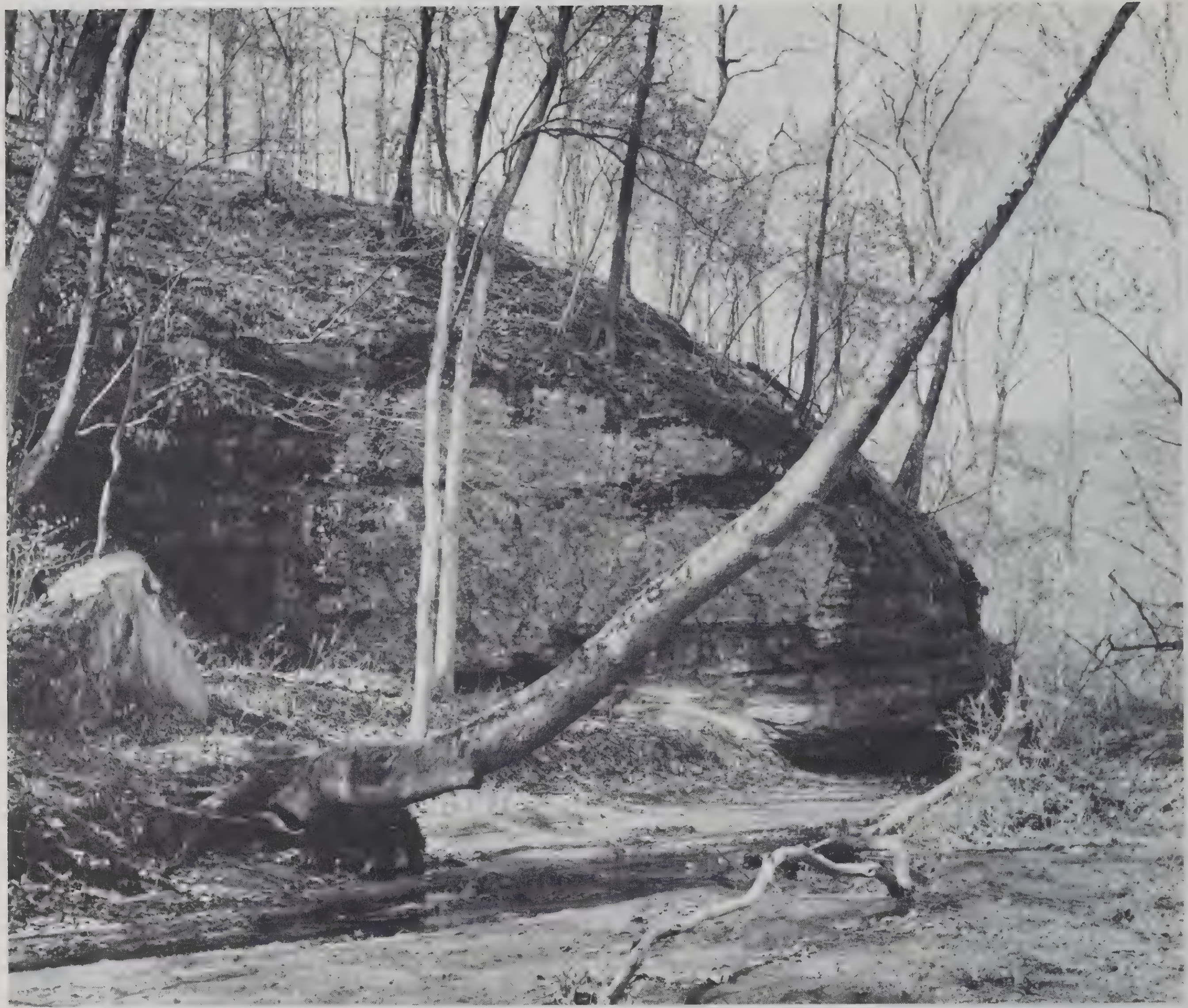

Fig. 19.—Rocky Branch area. This view from the bed of Rocky Branch shows a cliff, the undercut formed by the stream, and the steep slope above the cliff.

Ravine slopes support vegetations that range from the xeric to the mesic. The driest slopes maintain a forest of black oak, northern red oak, shagbark hickory, and other species. Poverty grass, various mosses, and lichens are abundant on the dry soil. The moist ravine slopes sustain a forest of beech, hard maple, hop hornbeam, redbud, flowering dogwood, and other arborescent species. Beech-drops, Christmas fern, wild hydrangea, and arrowwood, as well as numerous mosses, grow on these slopes. In one locality at the summit of a sandstone cliff, sphagnum moss is abundant. In another locality the walking fern, hepatica, and asters grow together in patches of moss on large sandstone blocks that lie above the floodwaters of the creek.

The sandstone cliffs possess a flora of mosses and liverworts; *Conocephalum conicum* is the common species. In the recesses wild hydrangea and several species of asters and goldenrods, as well as the maidenhair fern, find places in which they can live. Partridge berry is not uncommon at the tops of the cliffs, and it grows elsewhere with mosses. Lady fern thrives in some places at the cliff bases.

The upland woods is one of oaks and hickories. The forest is dry, and the floor supports mosses, lichens, poverty grass, and other xeric species. Nodding ladies'-tresses, which blooms as late as mid-October, grows in the open parts of the upland woods.

The abandoned fields maintain a mixture of herbs and varying numbers of trees and shrubs scattered here and there. In a field abandoned in 1958, one of the few woody plants observed in 1961 was the blackberry. In older fields smooth sumac, black walnut, tulip tree, northern red oak, and American elm have become established and perhaps are the beginnings of a deciduous forest that eventually will dominate the fields.

Rocky Branch is of interest botanically because

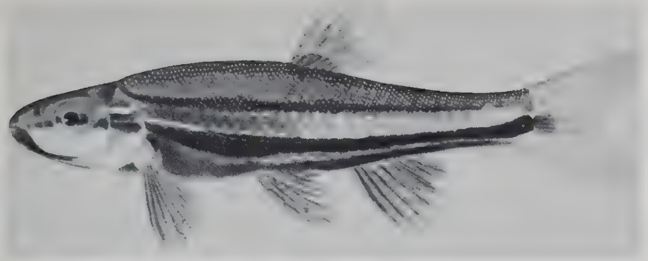

Fig. 20.—Southern redbelly dace, a brightly colored inhabitant of spring-fed streams of Illinois.

it lies in the westernmost natural limit of the black gum and the tulip tree in central Illinois. In addition, several species of orchids grow here. According to Stover (1930), the ground pine, *Lycopodium lucidulum,* throve on the sandstone. Irresponsible collectors and vandals have destroyed all traces of this club moss at Rocky Branch. The absence of sizable forest trees indicates that the original forest was felled at some earlier date. Additional botanical studies have been made by Ebinger & Parker (1969) and by Hellinga & Ebinger (1970).

The southern redbelly dace (Fig. 20); blacknose dace; two-lined salamander; several rare land snails, including *Zonitoides limulatus* and *Polygyra obstricta*; the thrips, *Eurythrips virginianus*; and the plantbug, *Neolygus belfragii,* all animals of unusual occurrence in Illinois, are found at Rocky Branch.

The Nature Conservancy purchased 175 acres of Rocky Branch and transferred title, with a reverter clause, to Eastern Illinois University. The area has served as an outdoor laboratory for students of botany and zoology at Eastern Illinois University for more than 4 decades.

17. EMBARRAS RIVER

The Embarras River from Greenup to Newton, in Cumberland and Jasper counties, is unpolluted and mostly unmodified and represents one of the finest aquatic natural areas remaining in Illinois. The river itself has a wide variety of habitats and supports a diverse fish fauna. The wooded floodplain along the river also is unmodified through much of the area.

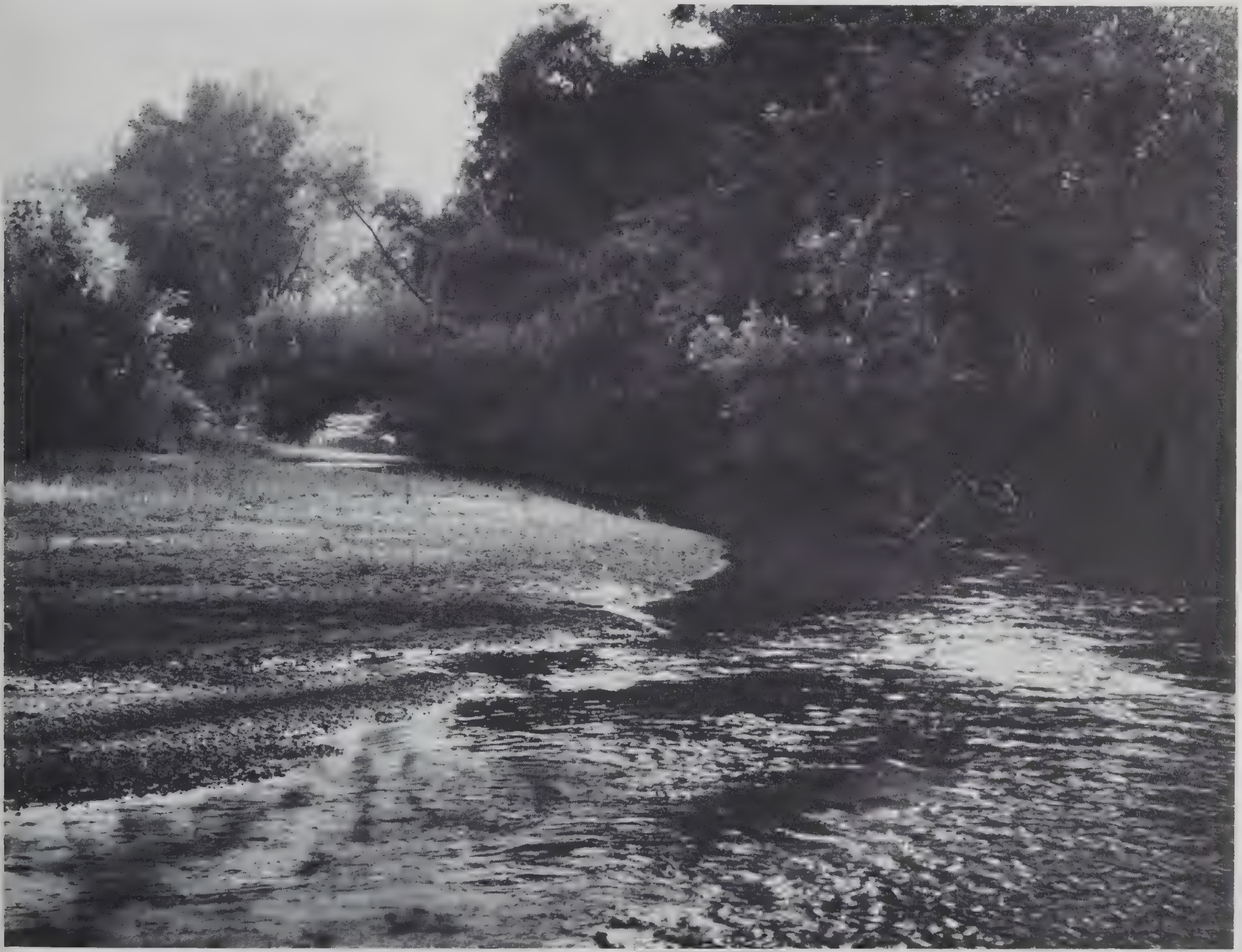

Fig. 21.—Embarras River near Greenup, Cumberland County. The Embarras has many fast riffles bordering sand and gravel bars that alternate with deep, quiet pools.

The moderate-sized, high-gradient Embarras River has extensive deposits of gravel and sand (Fig. 21) offering habitats to several unusual Wabash Valley fishes. The harlequin darter occurs nowhere else in Illinois or in the north-central states. Other fishes in the Embarras that are rare or limited elsewhere in Illinois are the eastern sand darter, mountain madtom, dusky darter, and greenside darter.

A notable terrestrial animal of the area is the timber rattlesnake, found in the wooded, rocky hillsides along the river.

The Embarras from Greenup to Newton is in private ownership, but access is available at the many bridges crossing the river. Sport fishing activity is moderate to heavy, with the major sport fishes being the channel catfish, spotted bass, longear sunfish, white crappie, and flathead catfish.

The Embarras River is dammed at Charleston, north of the area of interest. Smith (1968) discussed the unusual fishes of the Embarras and warned that modification of the river would eliminate the harlequin darter and decimate other fishes that are rare in Illinois. The natural state of the Embarras River and its resultant large populations of fishes seldom encountered elsewhere in Illinois were major factors in its selection as a site for life-history studies on the dusky darter (Page & Smith 1970) and the slenderhead darter (Page & Smith 1971).

18. AN ILLINOIS CENTRAL GULF RAILROAD PRAIRIE

A little over a century ago much of east-central Illinois was flatland prairie. Although early settlers shunned this land as unsuitable for cultivation because of a belief that only forest soils were fertile, later ones found it extremely productive and valued it highly. After a suitable plow had been perfected to break and turn the prairie sod and after drain tile had been placed to lower the water level, vast stretches of prairie were converted to farmland. Now only remnants of prairie are left; they are along roadsides or railroad trackways. These remnants must be preserved if we wish any Illinois flatland prairie vegetation to remain for future generations to study and enjoy.

A prairie area located along the trackway of the Illinois Central Gulf Railroad between Laclede, Fayette County, and Alma, Marion County, is actually a series of remnants of the Twelve-Mile Prairie of south-central Illinois. Numerous stretches along this track-

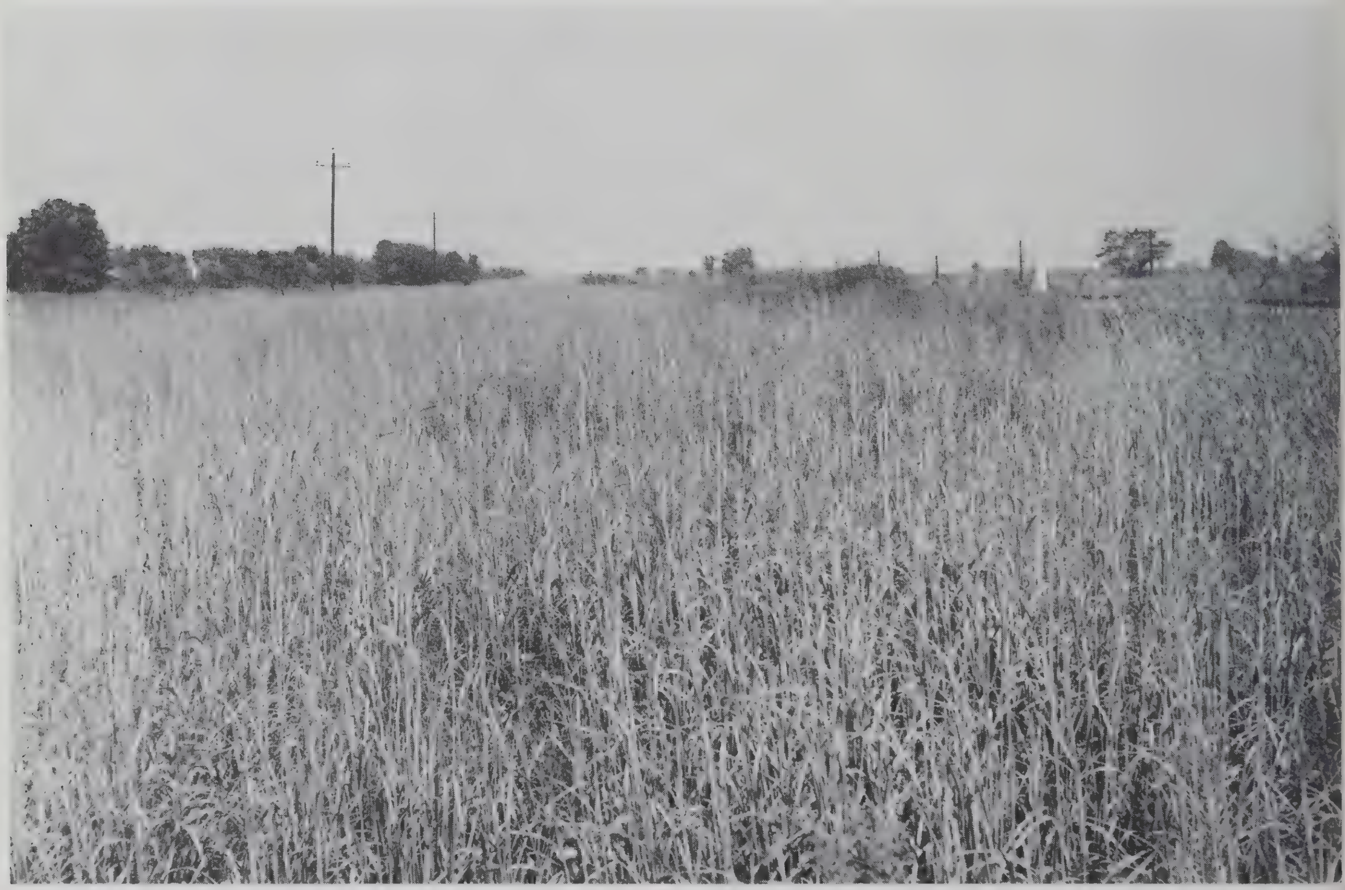

Fig. 22.—An expanse of big bluestem. This grass is the dominant plant in many of the flatland prairie remnants of central Illinois.

way have been plowed for the production of farm crops or of nursery stock. Some stretches that were cultivated have been abandoned and have reverted to a prairie type of vegetation.

The area is relatively flat except for those places where small streams have eroded into the flatlands. A century ago the drainage was poor, and the flatlands between the streams were very wet except in late summer, the dry season. At that season giant cracks appeared in the clay soil. Today numerous ditches along the railroad and highway drain the land rapidly. What effect the drainage had on the biota no one knows, as no one carefully studied these prairies a century ago.

The plants of the area are typically those of the tall-grass prairie. Big bluestem (Fig. 22) is the usual dominant although switchgrass and Indian grass are locally abundant and occasionally dominant. In the wettest parts of the prairie, prairie cordgrass is the dominant plant and densely covers the ground. In places of little disturbance, the prairie is a patchwork of a few species covering sizable areas. In some sites big bluestem covers much ground, while a short distance away may be blazing stars, rosinweed, prairie-dock, compass plant, wild hyacinth, or one of the numerous goldenrods, as *Solidago rigida.* Shrubs in the prairie include New Jersey tea and lead plant.

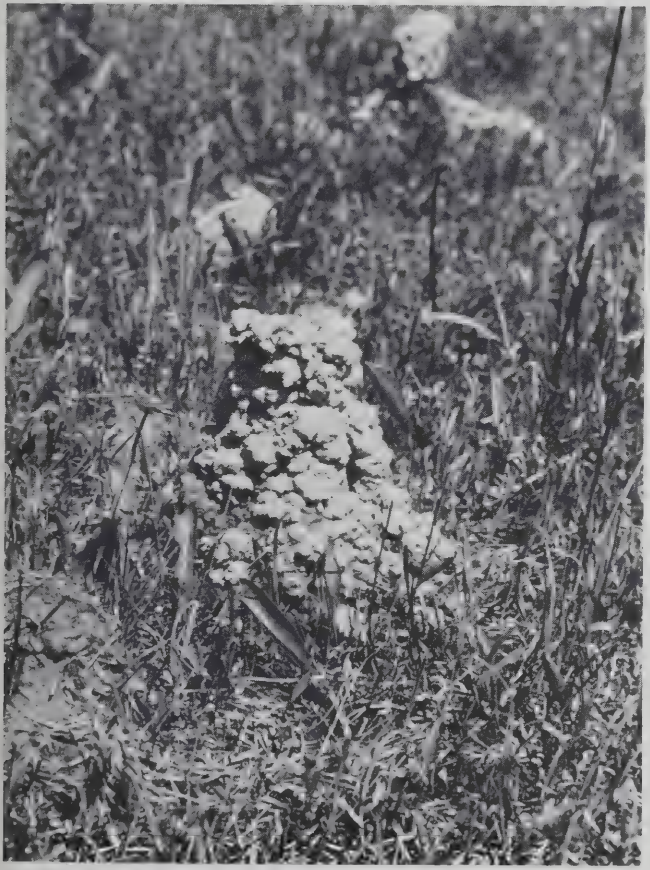

Fig. 23.—Mud turrets of chimney-building crayfish.

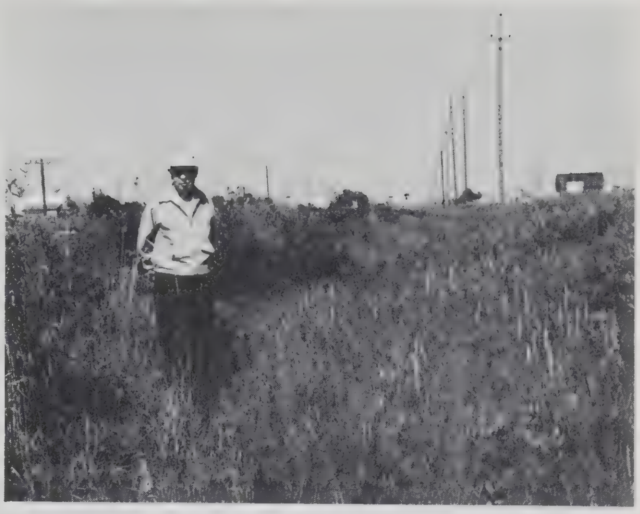

Fig. 24.—Prairie remnant in railroad trackway near Watseka, Iroquois County. Such remnants are all that remain of a once great expanse of flatland prairie.

The seasonal aspect of the prairie is interesting to observe. In early spring the prairie is dormant and shows little activity until May, except for the flowering of a few small and delicate cruciferous weeds, including Whitlow's grass. Some of the early flowers are small and rather inconspicuous, as blue-eyed grass, or small and conspicuous, as puccoon. The large and showy flowers of the beard-tongues appear in late May. In June the lead plant and the purple coneflower give a purple cast to the landscape. From then to the frosts of autumn a gradual but continual change of blossoms occurs, with the purple being replaced by yellow as the dominant color. Goldenrods and asters bloom profusely toward the close of the growing season.

Unfortunately, many people incorrectly believe the coarse prairie plants to be undesirable weeds. Within undisturbed prairie remnants very few, if any, noxious weeds—the type that cause the farmer trouble—can be found. Only after the prairie has been plowed or tremendously disturbed do the noxious weeds obtain a foothold. They then remain long after the land is no longer cultivated, and they even thrive in the secondary prairie type that develops.

Zoologically the Illinois Central Gulf Railroad prairie is of interest because of the interdigitation of prairie and forest habitats. This is one of the few areas where the ornate box turtle, a prairie animal, lives side by side with the eastern box turtle, a forest creature. This prairie also provides ideal habitat for the crawfish frog. In the spring, turrets (Fig. 23) of a chimney-building crayfish, *Procambarus gracilis,* are conspicuous as one drives the highway bordering the prairie. Prairie insects are now becoming rare because of the widespread destruction of their habitat by plow and pesticide. They still abound, however, in the Illinois Central Gulf Railroad prairie. The area is the type locality of *Anaphothrips sandersoni,* a thrips that lives only on prairie cordgrass.

The trackway prairie between Laclede and Kinmundy, owned by the Illinois Central Gulf Railroad, has been little disturbed during the past 7 years by the railroad except where the safety of train operation required it. It is a credit to the Illinois Central Gulf that it is instrumental in preserving this heritage. Credit must also be given to the Toledo, Peoria and Western Railroad for preservation of a prairie remnant along their trackway east of Watseka (Fig. 24).

19. DEVIL'S PROP

Devil's Prop is the local name applied to a ravine area in the northwest quarter of section 25, T. 1 S., R. 3 E., 2 miles south of Divide, a very small community in north-central Jefferson County. The ravine has been carved from the sandstone that underlies the area. At one place a pillar of sandstone appears to support the cliff (Fig. 25). From this pillar, or prop, the locality received its name—Devil's Prop.

The upland to the west and northwest of the ravine has been disturbed by agricultural pursuits. Some of this land has served as pasture. On the southeast side of the ravine a part of the upland has served as pasture and another part is a fallow field that is unpastured. In the fallow field certain prairie plant species have persisted and are common. These include Indian grass, little bluestem, blazing star, American feverfew, goldenrods, and asters. Broomsedge grows in this area. The forests of the upland contain shagbark hickory, red cedar, black-jack oak, and post oak. Poverty grass, pencil-flower, and several species of three-awn grass grow on the floor of the relatively open woods. Sizable patches of mosses of several species and some lichens form patches on the soil. The orchid, *Spiranthes grayi,* is not uncommon in the fallow field, and a few plants grow in the woodland border.

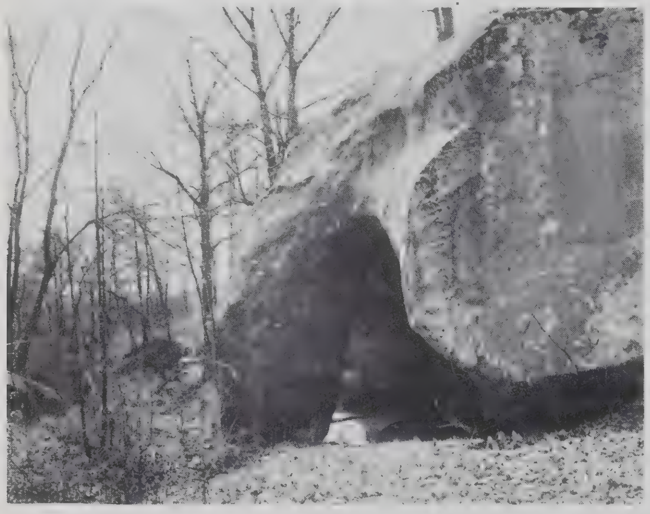

Fig. 25.—Devil's Prop area. A pillar of sandstone that appears to support the cliff above supplies the name for this area near Divide, Jefferson County.

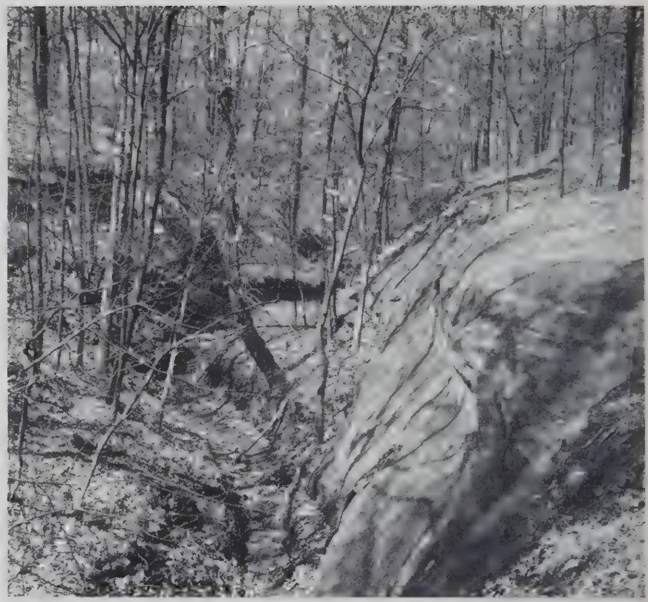

Fig. 26.—A narrow, V-shaped valley through which a small stream flows in the Devil's Prop area.

At one place the small stream flows through a narrow, V-shaped ravine (Fig. 26). In some places the sandstone of the steep sides is exposed and in other places covered with a thin layer of soil. Much of the steep slopes is covered with a growth of mosses, including hairy-cap moss. On the less steep slopes and on the floor of the widest portions of the ravine grows a deciduous forest; black gum, northern red oak, bitternut hickory, shadbush, white oak, and hop hornbeam are some of the tree species. Wild hydrangea and winged sumac are common shrubs in this forest.

The fauna is typical of southern Illinois habitats of this type.

Devil's Prop, with an area of 40 acres, was a gift of Dr. Carl Schweinfurth in 1970 to The Nature Conservancy. Thus, this delightful spot in Jefferson County has been set aside as a nature preserve so that future generations may also enjoy it.

20. BEALL WOODS

Beall Woods Nature Preserve is located east of Keensburg or about 5 miles southwest of Mt. Carmel, Wabash County. To the south lies a small community known as Rochester. The preserve, a part of Beall Woods State Park, is a part of section 11, T. 2 S., R. 13 W. It has an area of 290 acres.

Beall Woods is the only sizable, near-virgin remnant in Illinois of the once extensive deciduous forest of the Wabash River valley. Because of the richness of species and the immense size of the trees, the forest of the Wabash valley was considered by some to be one of the wonders of the world. Except for Beall Woods, it was lost in Illinois by clearing for cropland or by lumbering operations. Beall Woods itself almost met such an end, but devoted and influential citizens, a sympathetic governor, and a determined director of the Department of Conservation made its purchase and preservation possible.

Bottomland forest grows along the Wabash River and on the floodplain of Coffee Creek, a tributary of the Wabash that meanders through a part of Beall Woods. This creek received its name because in pioneer days a boat carrying coffee capsized at the mouth of the then unnamed stream. Some sizable trees grow on this bottomland. Large sycamores can be found, Shumard's oak, bur oak, and big shellbark hickory are represented by specimens over 3 feet in diameter. Hackberry, white ash, sweet gum, and Kentucky coffee-tree are a few other trees of this bottomland. The low bluffs of Coffee Creek support some sizable specimens of northern red oak and chinquapin oak. The upland forest is rich in arboreous species. Here one can observe large tulip trees, black oaks, white oaks, and shagbark hickories. Beech also grows here. Flowering dogwood, papaw, hop hornbeam, and mulberry are a few of the understory trees. The herbaceous flora is typical of the deciduous forest of eastern Illinois. Jack-in-the-pulpit, green dragon, bloodroot, toothwort, spring beauty, purple trillium, and dwarf larkspur are a few of the herbaceous species. Ashby & Ozment (1967) listed 340 species of vascular plants in the preserve.

Over 100 different birds have been observed in Beall Woods. The pileated woodpecker is one of many that are delightful to see and to hear. The land snail, *Mesomphix friabilis,* rare in Illinois, occurs in Beall Woods.

That portion of the Wabash River adjacent to Beall Woods is an especially noteworthy stream segment, with a variety of habitats supporting populations of fishes rare elsewhere in Illinois. These fishes, the mountain madtom, northern madtom, speckled chub, mimic shiner, and goldeye, combine with the floral and avian elements of Beall Woods to make the area one of extreme biological interest.

The visitor to Beall Woods should go first to the Red Barn Visitor Center, where he will receive material to guide him on his visit. It is a short distance from the Center to the forest, and not far from the edge of the woods he has a choice of several trails through the preserve.

Although Beall Woods is theoretically protected because it is in the Illinois Nature Preserve System, a threat exists. A coal seam lies 790 feet beneath the surface of this preserve. Recently an agreement has been reached between a mining company and the Department of Conservation which provides for the mining of a maximum of 40 percent of the coal and the leaving of 60 percent for support.

21. ILLINOIS CAVERNS

Illinois Caverns, in the north-central part of section 31, T. 3 S., R. 9 W., Monroe County, are also known as Mammoth Cave of Illinois, Eckert's Cave, and Burksville Cave. The cave is entered via a stairway descending one of the numerous sinkholes in the area. As described by Bretz & Harris (1961: 69–70) the cave is narrow, long, and crooked; has a small stream meandering along the floor; and has occasional accumulations of fallen rocks.

The cave has representatives of a number of interesting and unusual animals. Among the most evident are the scuds which can be observed in large numbers in the cave stream. The scuds in the cave are *Gammarus acherondytes,* a rare species known only from caves in Monroe and St. Clair counties, Illinois; *Gammarus troglophilus,* a large, relatively rare scud with a range limited to small areas of Illinois and Missouri; and *Bactrurus brachycaudus,* a slender eyeless species occupying subterranean habitats in southwestern Illinois and eastern Missouri.

Also found in Illinois Caverns are cave-adapted millipedes, flatworms, spiders, salamanders, the rare springtail, *Tomocerus missus* (Mills 1948:358), and the white, eyeless, aquatic sowbug, *Asellus packardi.*

A tour of part of the cave may be made after contacting the custodian. The large passage and relatively flat floor make Illinois Caverns easier than most caves to walk through and examine.

22. FULTS HILL PRAIRIE

Fults Hill Prairie is located on the bluff south of Fults Creek, southeast of the village of Fults in Monroe County, about midway between Valmeyer and Prairie du Rocher. The prairie is a part of old French land grants, the longest boundaries of which were perpendicular to the bank of the Mississippi River. Such boundaries were common in St. Clair, Monroe, and Randolph counties.

The bluff on which the prairie is located trends northwest to southeast; the brow slope faces southwest. This bluff, like others in the vicinity, is tall, towering more than 300 feet above the adjacent bottomland (Fig. 27). The limestone bedrock is exposed for some distance as a tall cliff. The toe slope of the bluff is talus. A blanket of loess caps the bedrock to form the brow slope, which varies in width. This slope is widest at the northwest, where there are sizable spurs and coves. Southeastward the brow slope

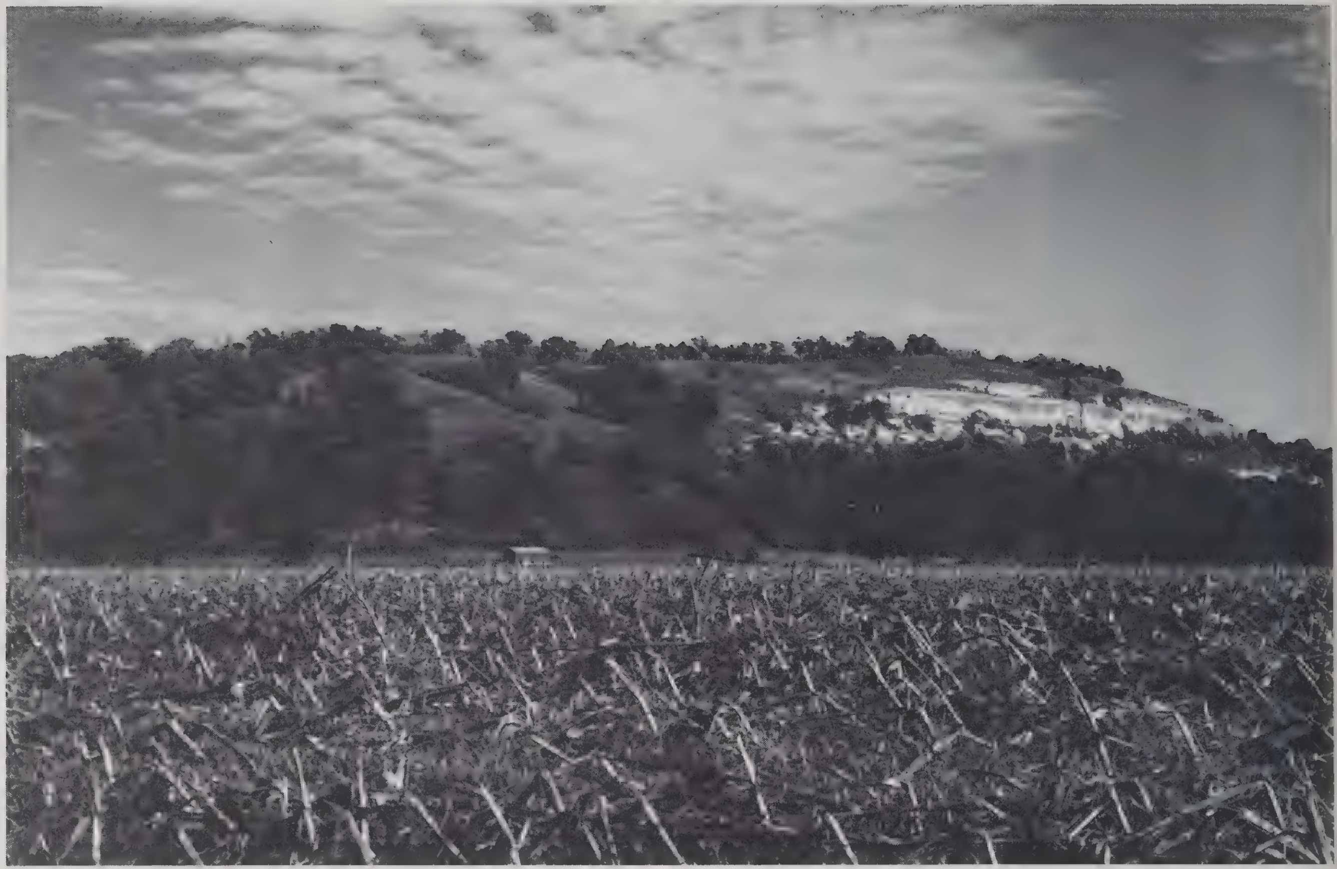

Fig. 27.—Fults hill prairie, southeast of Fults, Monroe County, as seen from the adjacent bottomland. Several rare species of plants and animals live on this bluff.

is not so wide, and the spurs and coves are poorly defined. At the extreme southeast, however, the brow slope widens and supports a broad expanse of prairie.

Vegetation of the bluff is of two types. The toe slope and the larger coves on the brow slope support deciduous forest. The spurs and the remainder of the brow slope are prairie. At the top of the cliff is a narrow rock ledge. The tall cliff faces are devoid of plants except for a few ferns and a few composites.

Fults Hill Prairie is not rich in plant species. As on other hill prairies, little bluestem is the dominant grass. The rare or semirare species this hill prairie contains make it important as a natural area. The bedstraw, *Galium virgatum,* is known in Illinois only at this site, where it grows abundantly at the base of one prairie spur. Scattered plants of bluehearts grow in this prairie. The rare *Heliotropium tenellum,* first reported in Illinois from this site, and stickleaf grow on the rock ledge.

The bluffs at Fults have some unusual animals. Among the vertebrates are the eastern narrow-mouthed toad, Great Plains rat snake, coachwhip, flat-headed snake, six-lined racerunner, and the ornate box turtle. An especially unusual invertebrate for Illinois is the scorpion, *Centruroides vittatus.* It has been found in Illinois only at Fults, and this is the northernmost record for this species.

Fults Hill Prairie and bluff is owned by the Illinois Department of Conservation and forms a part of the Fults Hill Prairie and Kidd Lake Marsh Nature Preserve.

23. FOUNTAIN BLUFF

Fountain Bluff, in Jackson County, is located south of Gorham and north of Grand Tower. It is an outlier of the bluffs of the west side of the Mississippi River valley; it was isolated by the diversion of the river from its main valley on the east into a narrower valley on the west. The older valley on the east is 4 miles wide; the one on the west is about 1 mile wide.

Fountain Bluff is 4 miles long and 1.8 miles across at the widest point; it has a perimeter of slightly more than 10 miles. Limestone of the Chester series, which scarcely outcrops at the south end of this outlier, is overlain with Caseyville sandstone. This massive sandstone forms the spectacular cliffs of Fountain Bluff. In a number of places the sandstone has been eroded to form large ravines or small valleys, some of which have been named. Loess caps the sandstone. The highest elevation on Fountain Bluff is 779 feet above sea level, or 419 feet above the floor of the valley to the east and about 430 feet above the Mississippi River to the west.

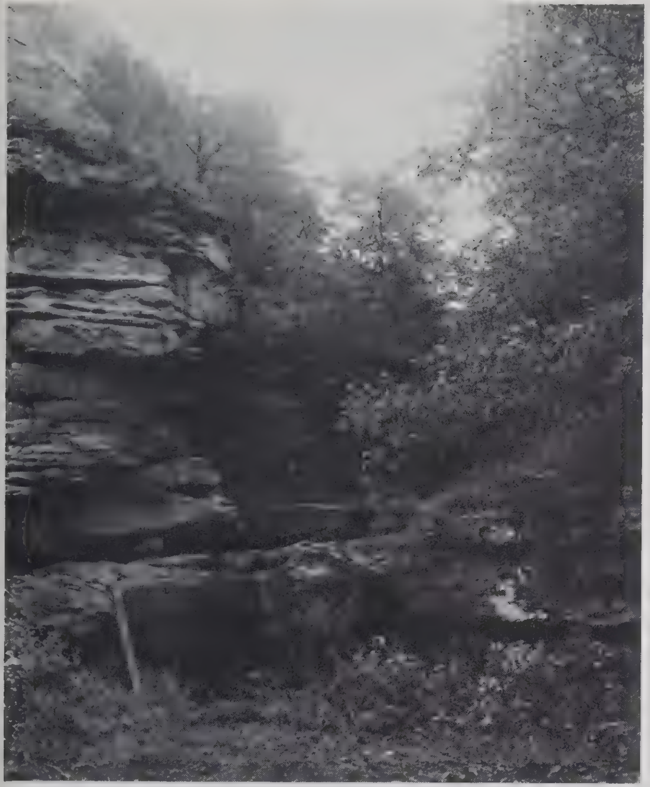

Fig. 28.—Mouth of the ravine at the site of the old Fountain Bluff station. This is the only sizable break in the tall sandstone cliff in the north side of the bluff.

Approximately a dozen farm homes are located at the base of the cliffs and in the largest ravine, known as Happy Hollow. A road follows the creek through Happy Hollow for a mile before it ascends to the top of the ridge on the west and then trends about a mile northeastward to the point of highest elevation, the site of Fountain Bluff Lookout Tower, a structure removed before 1950. On the east side of Fountain Bluff, three cemeteries, Goodbread, Henson, and Hudson, occupy small areas. A railroad, a branch of the Illinois Central Gulf from Carbondale, skirts the base of Fountain Bluff on the north and west. Years ago Fountain Bluff station stood at the mouth of a beautiful ravine on the northwest side of the bluff (Fig. 28). Later a dam was constructed across this ravine, near its mouth, to impound water for a swimming pool. Both station and pool have disappeared. The pool was filled by silt carried in by running water. The silt now supports semiaquatic and mesic plants.

Fig. 29.—Japanese honeysuckle in the Fountain Bluff area. This plant forms a dense cover over the ground and on shrubs; it also forms a dense columnar growth on tree trunks.

On the west side of Fountain Bluff is another large ravine, Trestle Hollow. On the southwest, not on the bluff but on the riverbank and adjacent bottomland, several industries—a grain loading dock, a sand and gravel company, and a power station—have developed. Three power lines from the power station cross Fountain Bluff. Two extend eastward; the third stretches northward for some distance on the crest of the bluff ridge along the Mississippi River.

The vegetational cover of Fountain Bluff is mostly deciduous forest interspersed with small prairie openings and formerly one large hill prairie. A small area serves as agricultural land for crop and livestock pro-

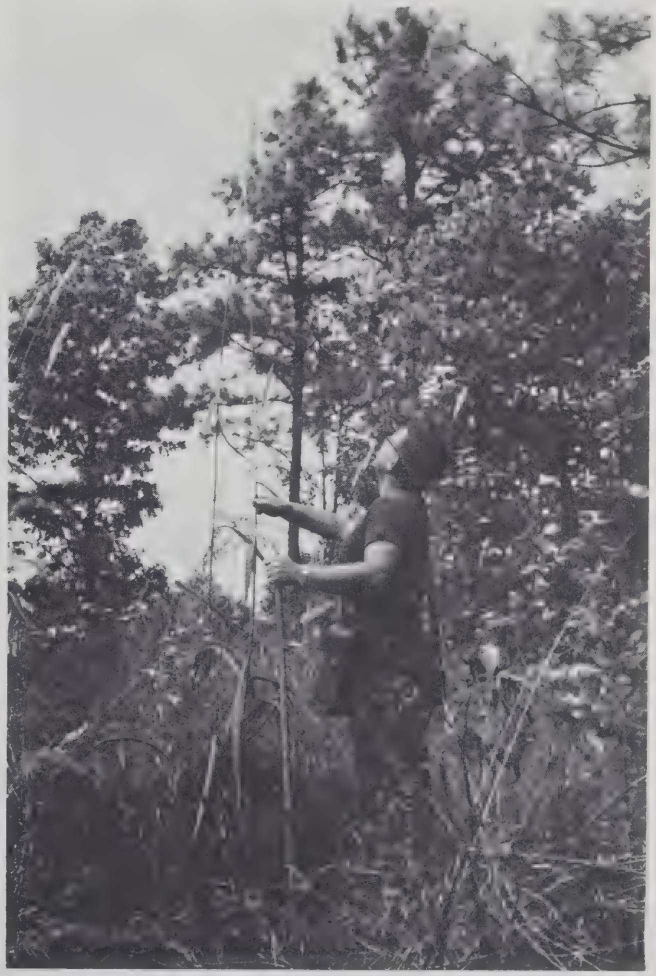

Fig. 30.—Plume grass on Fountain Bluff. These culms are over 8 feet tall.

duction and as a site for a commercial enterprise. The dominant tree of the forest appears to be the tulip tree. This tree grows on the slopes and in the ravines. Associated with this species is northern red oak, black oak, white oak, chinquapin oak, and white ash. In the valleys or ravines the sycamore, beech, honey locust, hard maple, and American and slippery elms grow profusely. Black locust evidently was once widely planted in the area. The understory trees include sassafras, redbud, flowering dogwood, hop hornbeam, Iowa crabapple, and blue beech. Common shrubs and vines are poison ivy, spicebush, wild hydrangea, and the introduced Japanese honeysuckle. In some places this honeysuckle has become a pest; it covers the ground surface, forms a dense growth on tree trunks (Fig. 29), and completely covers small shrubs. Many ferns and herbaceous flowering plants, including rare orchids, grow in the moist ravines. Mosses are ordinarily common on the soil surface, and both mosses and liverworts abound on the moist sandstone outcrops and cliffs in the ravines. Of interest to botanists are the numerous patches of plume grass that are scattered on the ridge top to the north and at the base of the bluff to the east. This grass may reach heights of 8 feet or more (Fig. 30).

The prairie openings are small, and most of them are on the ridge tops (Fig. 31). The one sizable hill prairie of this area was situated on the southwest-facing ravine slope at the northern end of Fountain Bluff, but invasion by forest has reduced it to a few small openings. The dominant grass of the prairie types is little bluestem; big bluestem and Indian grass are not uncommon.

The Illinois wood rat, a subspecies of the Eastern wood rat, is one of the unusual animals at Fountain Bluff, being known from only two other areas in Illinois (Klimstra 1969:7). In winter, at temperatures above freezing, the wingless insect, *Boreus brumalis,* wanders about on mosses or snow (Stannard 1958). Fountain Bluff and a few other localities in southwestern Illinois are the isolated stations of *B. brumalis,* far removed from its main range in the eastern states.

Other invertebrates of interest at Fountain Bluff are the land snails, *Retinella rhoadsi* and *Bulimulus dealbatus,* recorded in Illinois only from this area; the thrips, *Dorcadothrips walteri,* also known in Illinois only from Fountain Bluff; the pseudoscorpion, *Larca granulata*; and the grasshopper, *Ischnoptera deropeltiformis.*

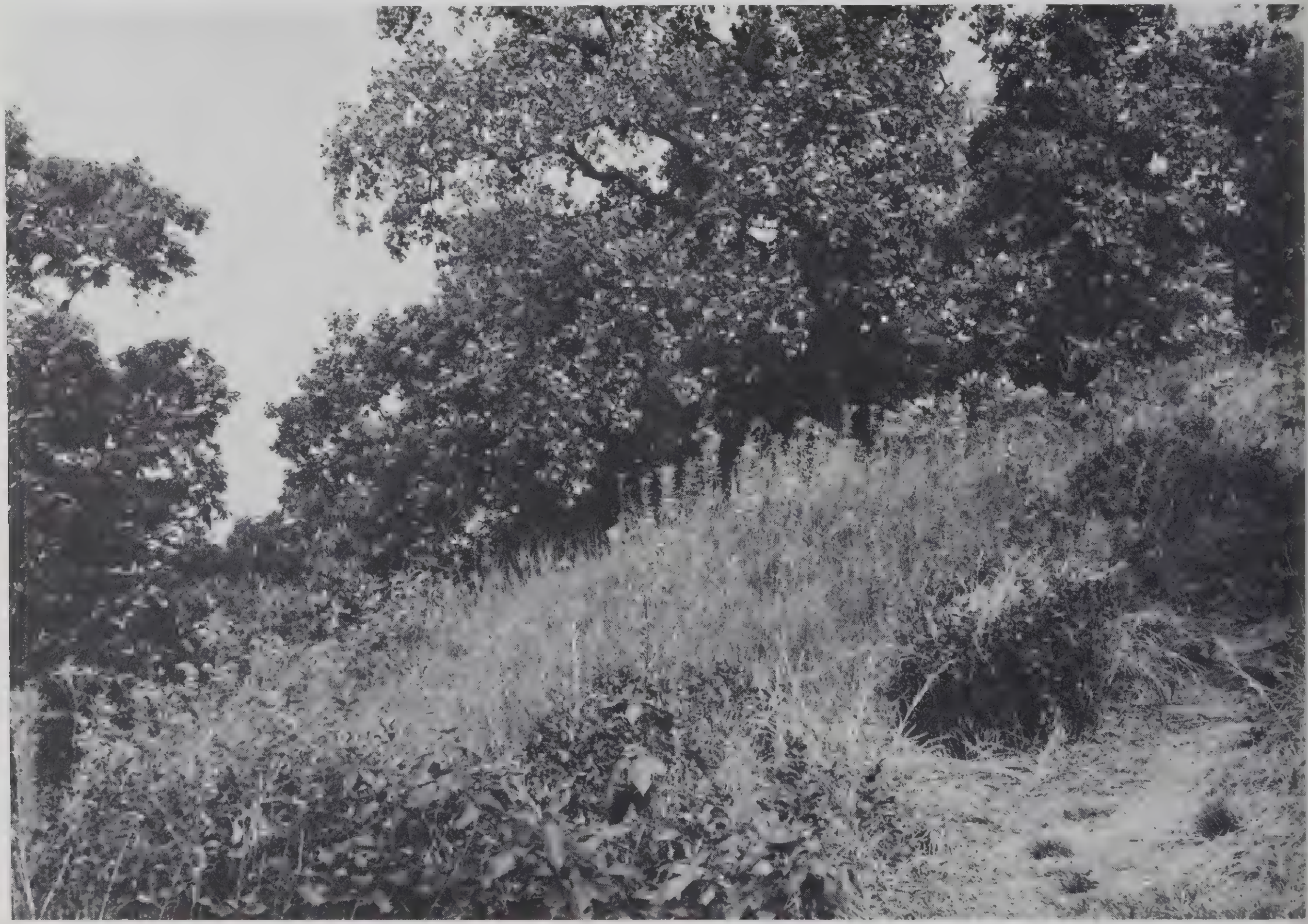

Fig. 31.—One of the small prairie openings on a ridge top on the western side of Fountain Bluff.

24. GRAND CANYON

Grand Canyon natural area, located about 8 miles southwest of Murphysboro, Jackson County, occupies the southeast quarter of section 35 and the southwest quarter of section 36, T. 9 S., R. 3 W.; the west half of section 1 and much of section 2, T. 10 S., R. 3 W.; it is more than 700 acres in extent. The names Chalk Bluff, Hickory Ridge, and Viney Ridge are applied to the area or to parts of it.

This natural area is a part of the bluff system of the Mississippi River valley. From the floodplain the bluffs rise precipitously 360 feet, reaching an altitude of 720 feet above sea level. The tall, west-facing cliff in section 2 is about 0.75 mile in length and is named Chalk Bluff. The cliff is plainly visible from Fountain Bluff, 4 miles to the west, and from other points in the river valley. Above the tall cliff lies a stony slope; loess caps the bluff.

To the north of Chalk Bluff is a large valley, not quite 0.25 mile across, that is tributary to the Mississippi. This tributary valley, known as Grand Canyon, has steep walls and cliffs. To the south of Chalk Bluff is Clear Creek. This stream flows in a rather broad valley approximately 0.5 mile wide and enters the Big Muddy River, which here flows southward through the Mississippi River floodplain. From Grand Canyon sizable ravines trend upslope to the south and from Clear Creek valley similar ravines trend upslope to the north to dissect the area into a series of deep ravines separated by ridges. The main ridge, which trends eastward from Chalk Bluff, almost midway between Grand Canyon and Clear Creek, is known as Viney Ridge. A half mile east of Chalk Bluff is Hickory Ridge. The elevation at this site is 740 feet. Fig. 32 shows a view of the ridges and bottomland taken from a fire tower that formerly stood on the crest of the ridge.

The ridges support a mixed forest, including such species as chinquapin oak, northern red oak, black oak, sweet gum, bitternut hickory, tulip tree, and red cedar. Hop hornbeam, Hercules' club, and redbud grow as understory trees. Poison ivy, smooth sumac, and winged sumac are common shrubs. In some places two species of greenbrier form dense, almost impenetrable patches. Plume grass grows profusely in some of the small openings of the ridge top and also on some slopes.

The ravine slopes support a forest that includes some of the species enumerated above and also beech, which is very abundant. The understory includes flowering dogwood, papaw, and, along the rivulets, the blue beech. On these slopes the Christmas, the maidenhair, the broad beach, the glade, and other ferns are not uncommon. In spring numerous wild flowers clothe the slopes.

In 1949 a small hill prairie occupied part of the west-facing brow slope at the northern extremity of Chalk Bluff. Little bluestem was the dominant grass. Scattered throughout the prairie were small hickories, sassafras, and white oak. In 1970 hill prairie no longer occupied this brow slope. White oak and hickories were present as in 1949, but so were beech, northern red oak, white ash, and hop hornbeam. Some of the shrubs were farkleberry, smooth sumac, fragrant sumac, poison ivy, and Virginia creeper. Prairie plants were few, both in numbers of species and individuals.

The bottomland forest beyond Chalk Bluff toward the Big Muddy River contains such species as overcup oak, swamp white oak, pin oak, pecan, and big shellbark hickory.

This bottomland woods is of special interest to herpetologists because it contains one of the best known snake dens in eastern North America. For many decades the Grand Canyon area has been visited by zoo personnel and other zoologists (Ditmars

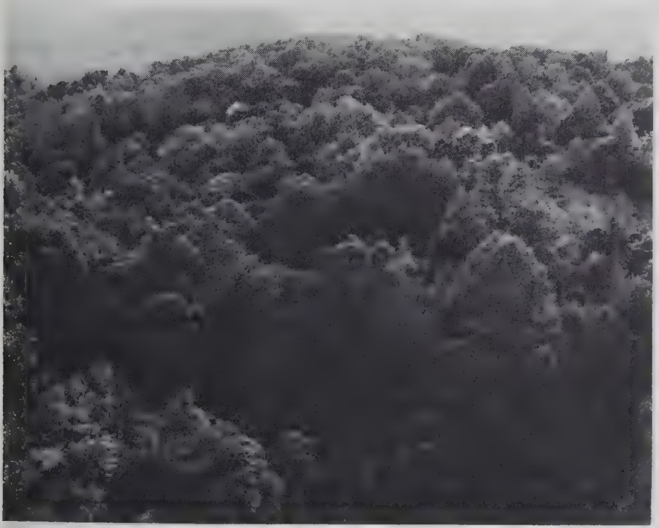

Fig. 32.—Deciduous forest as seen from Hickory Ridge Lookout Tower (since removed) in the Grand Canyon area.

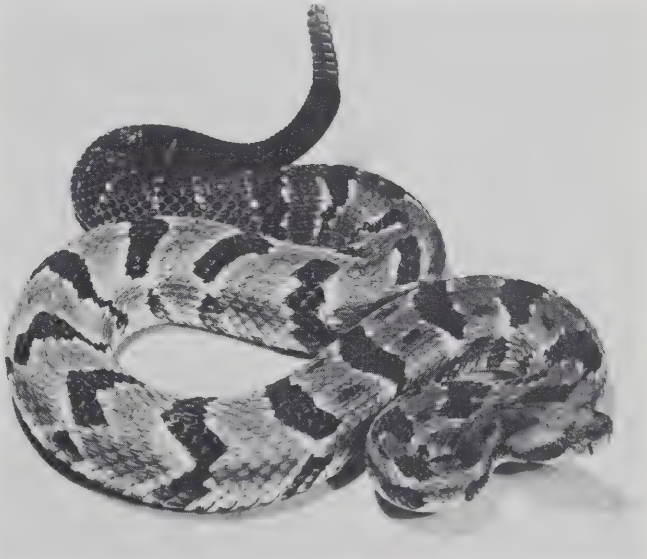

Fig. 33.—An adult timber rattlesnake from Jackson County.

1937:103; Minton & Minton 1969:179–180). The timber rattlesnake (Fig. 33), cottonmouth, copperhead, a great variety of harmless snakes and other reptiles, and numerous amphibians live in the area. Unfortunately, the area has also been visited by untrained and uneducated persons, some of whom love only to kill any animal that creeps on the surface of the earth. Although for a long time the snake den was well off the beaten trail, no longer is this true.

Occasionally a visitor to Grand Canyon is rewarded by finding the eastern hercules beetle, *Dynastes tityus.* In size this southern beetle exceeds that of our smallest mammal, the pigmy shrew.

Grand Canyon harbors some rare and semirare plant species: the club moss, *Lycopodium lucidulum,* which grows on a sandstone cliff of one of the tributary ravines; sphagnum moss, which covers a sizable, moist sandstone outcrop in another ravine; and several orchids, including Wister's coralroot and twayblade.

Much of the Grand Canyon natural area is under the supervision of the U. S. Forest Service, but some parts remain in private ownership.

25. LaRUE-PINE HILLS ECOLOGICAL AREA

One of the most beautiful, unusual, and outstanding natural areas in Illinois is Pine Hills and the adjacent LaRue swamp in Union County. No matter what the season, this place abounds in natural beauty. It is located in sections 4, 9, 10, 15, 16, 21, 22, and 28, T. 11 S., R. 3 W.

The LaRue-Pine Hills Ecological Area is bordered on the west by a railroad, on the east by the road at the crest of the bluff, on the north by the levee and the road north of the levee at the base of the bluff. The southern boundary, which is south of the road from LaRue, is irregular. The preserve encompasses an area of 1,996 acres, of which almost 1,905 acres are under the National Forest Administration.

The bluffs of the Mississippi River that form Pine Hills are underlain with cherty limestone that outcrops to form sizable cliffs up to 100 feet high (Fig. 34). Cherty slopes lie above the cliffs, and loess caps the bluffs. At the cliff bases, toe slopes of various sizes have been formed of rock fragments that have spalled from the cliff faces. The swamps are in the bottomland adjacent to the bluffs (Fig. 35). They occupy the old channel of the Big Muddy River, which enters the Mississippi River valley west of Murphysboro, Jackson County, and meanders southward along the bluffs into section 4, T. 11 S., R. 3 W., then southwestward and westward to enter the Mississippi River below Grand Tower. In earlier days the Big Muddy continued its course southward along the bluffs. Present-day Otter Pond and Wolf Lake, which lie south of the LaRue-Pine Hills Ecological Area, are parts of the old river channel. Big Muddy is an example of a Yazoo River type of tributary.

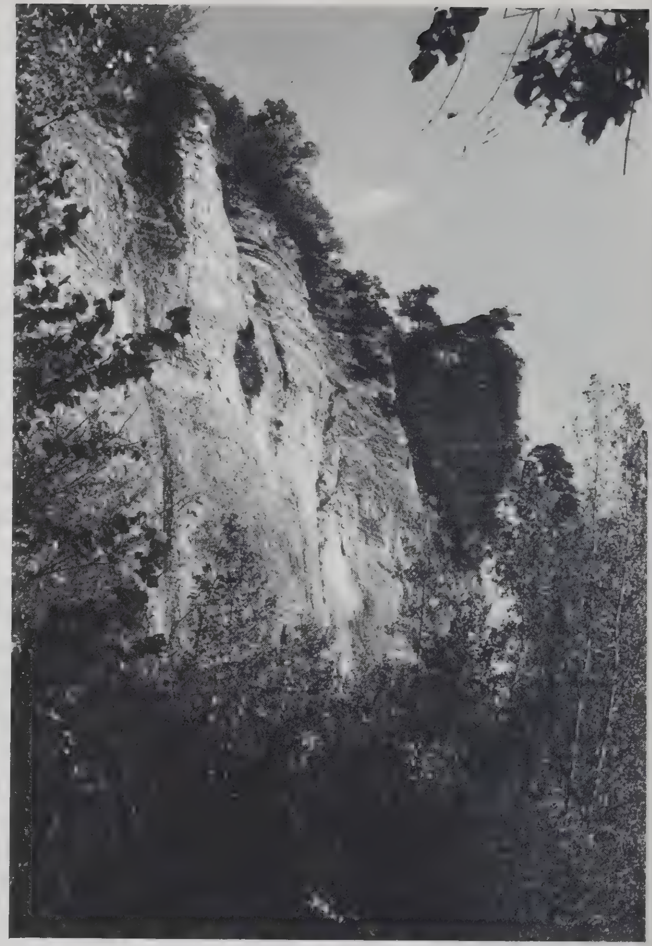

Fig. 34.—Cherty limestone cliff on the bluffs of the Mississippi River at Pine Hills. This cliff rises to a height of 100 feet above the nearby bottomland.

The vegetation of Pine Hills is mostly deciduous forest. Prairie openings and one hill prairie are found here. The toe or talus slopes of the bluffs are forested, as are the ravines that extend eastward into the bluffs. The south-facing ravine slopes are cov-

Fig. 35.—Bottomland swamp as seen from the bluff top in the Pine Hills area.

ered with xeric oaks and hickories and some prairie herbs, the north-facing slopes with mesic forest, including tulip tree and hard maple. The cliffs support few plants except scattered individuals of cliff brake, some species of goldenrod, especially Drummond's, and red cedar.

The brow slopes above the cliffs maintain forest in some places, prairie in others. Some of this prairie is of the typical hill type, with little bluestem the dominant grass, and some exists as small openings within the forest. The forest is a mixed deciduous type, with southern yellow pine and pink azalea as unusual species. Southern yellow pine is restricted in Illinois to two localities: Pine Hills and southern Randolph County to the north. Farkleberry is a common shrub on the Pine Hills slopes. These slopes are also the type locality of *Liatris scabra,* a species of blazing star that was first described from collections made here.

The swamps are of interest botanically for the occurrence of several species that are rare in Illinois. Several species of duckweeds, including *Wolffiella floridana,* live in the water of this swamp, as do frogbit and swamp loosestrife, the last a species more common much farther north. Here can also be found the rare grass, *Glyceria pallida.*

The vertebrates in this locality present a rich assemblage of northern, southern, eastern, and western elements occurring in relatively undisturbed habitats. They have been subjects of several investigations, including those by Gunning & Lewis (1955), Rossman (1960), Klimstra (1969), and Boyd et al. (1975). The unusual fishes are the spring cavefish, banded pygmy sunfish, bantam sunfish, spotted sunfish, and starhead topminnow. Unusual amphibians are the mole salamander, cave salamander, bird-voiced treefrog, and green treefrog (Fig. 36).

The swamps harbor the cottonmouth in sizable numbers, the green water snake, the mud snake, and many other more widely distributed species of snakes. On the bluffs are habitats supporting populations of many reptiles, including timber rattlesnakes and flatheaded snakes. Pine Hills is the only locality in Illinois from which the scarlet snake has been recorded.

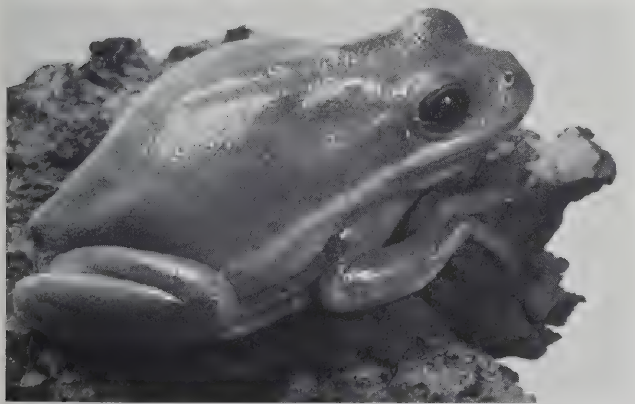

Fig. 36.—A subadult green treefrog from Union County. The green treefrog is bright leaf-green with a white lateral stripe and gold flecks on the back.

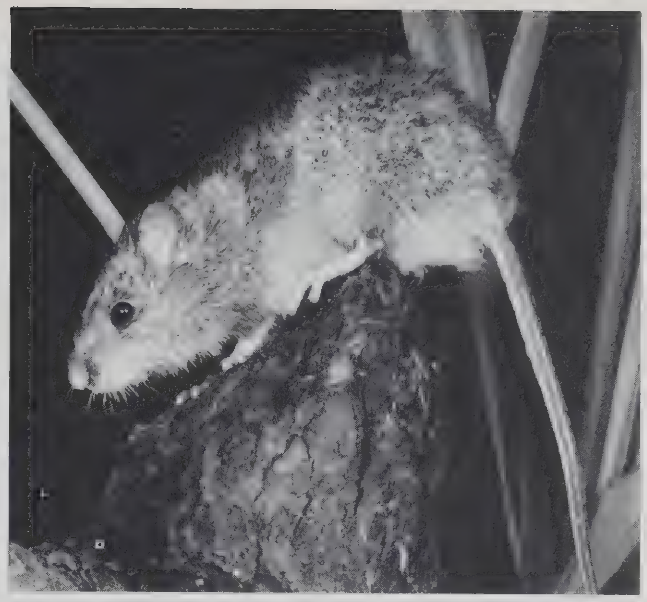

Fig. 37.—Rice rat, a small rodent inhabiting marshes and swamps of extreme southern Illinois.

The large bird community includes the Mississippi kite, many species of waterfowl, and a common egret rookery. The plaintive calls of the chuck-will's-widow and the mockingbird remind one that he is now in the southland. The Illinois wood rat, rice rat (Fig. 37), Indiana bat, evening bat, and bobcat are a few of the mammals rarely found in Illinois that are inhabitants of LaRue-Pine Hills Ecological Area (Klimstra 1969; Klimstra & Roseberry 1969; Smith & Parmalee 1954).

For the listener during the spring and early summer, the nightly performances of the amphibian choir, with pitches from the highest sopranos of treefrogs to the deepest basses of bull frogs, cacophonous but beauteous, is a never-to-be-forgotten experience.

Especially unusual invertebrates at LaRue-Pine Hills are an endemic scud, *Gammarus minus pinicollis* (Cole 1970); the dwarf crayfish, *Cambarellus shufeldtii*; the scorpionflies, *Boreus brumalis, Merope tuber,* and *Bittacus punctiger*; the stonefly, *Hastaperla brevis*; the thrips, *Heterothrips azaleae* and *Oxythrips divisus*; the grasshoppers, *Schistocera obscura* and *Neotettix femoratus*; and the butterflies, *Amblyscirtes carolina, Autochton cellus,* and *Atlides halesus.*

Part of Pine Hills and the adjacent swamps is in the Shawnee National Forest, part in the Southern Illinois University Biological Station, and part in private ownership.

To stop overexploitation of the flora and fauna by collectors, the U. S. Forest Service recently designated the area an Ecological Area, and collecting is allowed by permit only. At last this remarkable area has received some of the protection it has for so long needed and deserved. The staff members of the U. S. Forest Service who made this possible are to be commended for their action and deserve the thanks of the citizens of Illinois.

26. HORSESHOE LAKE

Picturesque Horseshoe Lake, located south of Olive Branch, occupies parts of 12 sections in T. 16 S., R. 2 W., in Alexander County. The outline of the lake, which somewhat resembles a horseshoe, possibly suggested the name. The lake was formed from an old meander of the Mississippi River, which is now several miles to the west. The east arm of the lake is approximately 3.75 miles long and 0.25 mile across. To the northwest is a mixture of small lakes and swamp areas. Stretching from the northwest are two arms. One trends southeastward, is about 2.75 miles long and 0.25 mile across, and joins the east arm about 0.5 mile north of the southern extremity of the lake. Between this, the central arm, and the east arm is an island about 2 miles long and 0.5 mile wide. The other arm, the western, trends southward for 0.5 mile, where a levee impounds the water and prevents its flow to the old lake bed that stretches on farther to the south. A dam and spillway at the south ends of the eastern and central arms control to some extent the water level of the lake. Overflow at the dam enters Lake Creek and flows northeastward into the Cache River. Runoff from the surrounding farmland and several small creeks to the north, including Pigeon Roost Creek, supply water to the lake. During dry seasons, several large wells augment this supply. The lake and some of the surrounding area serve as a state wildlife refuge.

The native vegetation of the refuge can be classified as (1) forest and (2) aquatic and semiaquatic. On the island and on some of the land to the west of the central arm are cultivated fields of corn, sunflowers, and soybeans. The products of these fields serve as food for the Canada geese that come here in huge numbers in October and remain until March.

Floating on or just beneath the surface of the lake, sometimes densely covering immense areas, are several duckweeds, including the rare *Wolffiella floridana*. The mosquito fern floats in such numbers on the water, either with the duckweeds or in pure stands, that the surface of some parts of the lake is completely covered (Fig. 38) and assumes a purplish hue. Hornwort and other aquatic plants grow submerged in the lake. Bald cypress and tupelo rise from the shallow water to produce the picturesque appearance of Horseshoe Lake (Fig. 39). In small, shallow pools of the west arm, American lotus covers large areas. The vast numbers of large, circular leaves rise from the water to heights of about 6 feet. In July and August thousands of cream-colored flowers, 6 inches or more across, appear over the leafy mass.

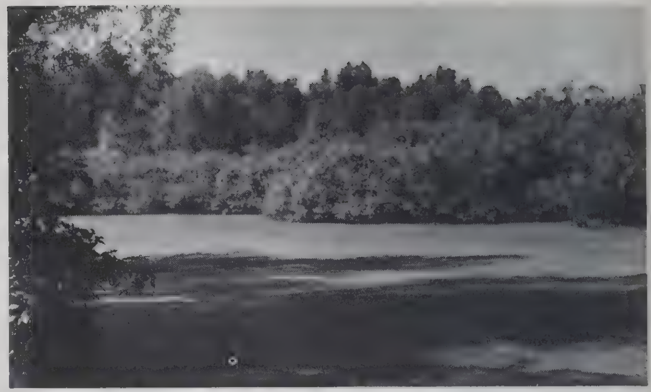

Fig. 38.—One of the coves of Horseshoe Lake. When this picture was taken, mosquito fern completely covered the surface of the cove to give the effect of a lawn rather than open water.

In the very shallow water along the shore, such plants as arrowhead, pickerel weed, and primrose-willow are frequently observed. Other plants of the fluctuating shoreline are buttonbush, swamp privet, swamp honey locust, swamp cottonwood, Drummond's maple, box elder, and numerous herbs, including *Eclipta alba*.

On slightly higher ground bordering the lake shore, other tree species grow in profusion. Shingle, pin, swamp white, overcup, and southern red are the most common of the species of oaks. Soft maple is common; basswood is scattered here and there, as are black walnut and pecan. Three vines are common on trunks of the trees: Virginia creeper, trumpet creeper, and poison ivy. Two additional vines, raccoon grape and passion flower, are less common but can be easily found. In the plant community bordering the lake, clearweed, false nettle, and water horehound are abundant.

The animal life at Horseshoe Lake includes numerous representatives of the Coastal Plain fauna, making it among the most interesting assemblages of animals in Illinois. Amphibians of the area are especially interesting, with large populations of species rarely encountered elsewhere in the state. Included among these are the marbled salamander, mole salamander, bird-voiced treefrog, and green treefrog. Rare reptiles at Horseshoe Lake are the broad-banded water snake, known from nowhere else in Illinois, and the green water snake, known only from Horseshoe Lake and LaRue-Pine Hills.

Other rare animals at Horseshoe Lake are the big-eared bat (Smith & Parmalee 1954:204); southeastern bat (Illinois Natural History Survey specimen); southeastern shrew; rice rat (Necker & Hatfield 1941:42, 53); bobcat (Klimstra & Roseberry 1969: 415); bald eagle (which has nested at Horseshoe Lake in recent years); Swainson's warbler; a crayfish, *Orconectes lancifer*, known in Illinois only from Horseshoe Lake (Page & Burr 1973:52); spotted gar; pugnose minnow; and brown bullhead.

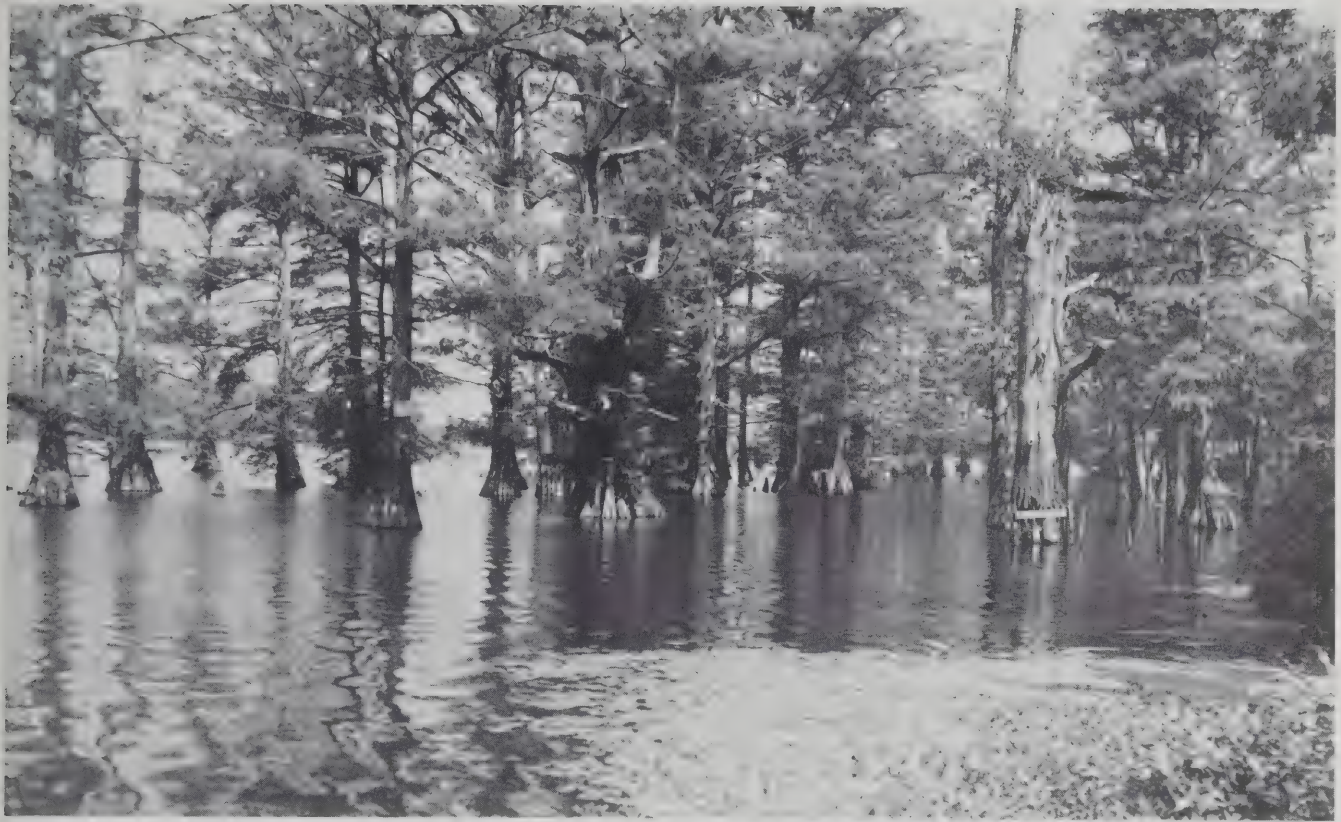

Fig. 39.—Bald cypress and tupelo growing in the water of Horseshoe Lake, Alexander County. Primrose-willow also grows in the water here (foreground).

Rare insects at Horseshoe Lake include a thrips, *Scirtothrips taxodii,* and plant bugs, *Pilophorus taxodii* and *Phytocoris taxodii,* living on cypress trees; a thrips, *Heterothrips aesculi,* living on buckeye; an earwig, *Vostox brunneipennis*; and two species of scorpionflies, *Boreus brumalis* and *Bittacus punctiger.*

Numerous picnic tables have been placed near the lake and close to some of the all-weather roads. The island is usually closed to the public. The overwintering geese attract to this area numerous hunters and bird watchers who, it is estimated, spend over a million dollars annually in Cairo and vicinity.

Horseshoe Lake Wildlife Refuge is under the supervision and control of the State of Illinois Department of Conservation.

The southern part of the island has been dedicated as a nature preserve in the Illinois system.

27. CACHE RIVER SWAMPS

Remnants of once-vast cypress swamps are found in a number of localities in southern Illinois, including the Cache River valley and the broad valley that extends from Belknap eastward to the Ohio River. In preglacial times it was not the Cache but an extension of the present Cumberland River that flowed through this valley; the Cache was then a tributary that entered the larger valley where it does now, that is, between Belknap and Forman, Johnson County. After glaciation, the Cumberland emptied into the Ohio; the Cache followed the preglacial valley of the Cumberland and flowed westward and southward to empty sometimes into the Ohio and sometimes into the Mississippi. In this valley are numerous remnants of cypress swamps, three of which are especially noteworthy for both plants and animals.

Two and one-half miles west and 1 mile north of Karnak was a sizable remnant of a cypress swamp. It occupied parts of sections 7 and 8, T. 14 S., R. 2 E., in Johnson and Pulaski counties. During the past few years the Johnson County segment of the swamp has been totally cleared, leaving wet, open land; the Pulaski County segment, in 1970, still contained cypress swamp, but some logging had been carried out. The river here serves as the county line. Illinois highway 37 traverses this swamp from north to south. The Cache River here occupies a part of the preglacial Cumberland valley.

During much of the year the ground is inundated, often by as much as 6 feet of water, but frequently in the dry season—late summer and early autumn—the water recedes, and it is possible to walk in the swamp. The large trees of this swamp are bald cypress and tupelo, both of which have buttressed bases. Many of the bald cypresses are surrounded by pneumatophores, or knees (Fig. 40), that grow up to 7 feet high. Other trees of this swamp are overcup oak, swamp cottonwood, Mississippi hackberry, river birch, Drummond's maple, swamp honey locust, and water elm. The last is limited in Illinois to a few of the cypress swamps.

Common shrubs in the Karnak swamp include swamp privet, buttonbush, and, less frequently but still locally abundant, Virginia willow. Trumpet creeper is a very abundant vine in this swamp; *Brunnichia cirrhosa* grows along the border.

The floor of the swamp near the border supports a growth of herbaceous plants, including lizard's-tail, false nettle, a rare milkweed named *Asclepias perennis,* and clearweed. Deep in the swamp the floor is mostly devoid of vegetation except for seedlings of some trees. On decaying logs that float when water is present or rest on the swamp floor in the dry season are found peculiar plant associations that have such species as clearweed, Virginia willow, beggarticks, the small composite known as *Eclipta alba,* and marsh St. John's-wort crowded together.

The large number of sizable bald cypress trees in this swamp is of interest to botanists. Some individual trees are 3.5–4.0 feet in diameter above the buttressed bases. Several specimens measure 5.0–5.5 feet in diameter and up to 100 feet in height. Also of interest to botanists is the polypody found growing as an epiphyte on a single ash tree.

Another cypress swamp remnant in the Cache River valley is a mile north and one-half mile east of Belknap, or slightly more than a mile southwest of Forman in Johnson County. It is located in the northeast quarter of section 36, T. 13 S., R. 2 E., and occupies about 100 acres. This swamp is in the preglacial Cache River valley and is near the point where the Cache enters the larger valley of the preglacial Cumberland. The area of biological interest embraces not only the cypress swamp, but also the forested bluff to the south of the swamp; at the base of the bluff is a spring, known as Bird Spring.

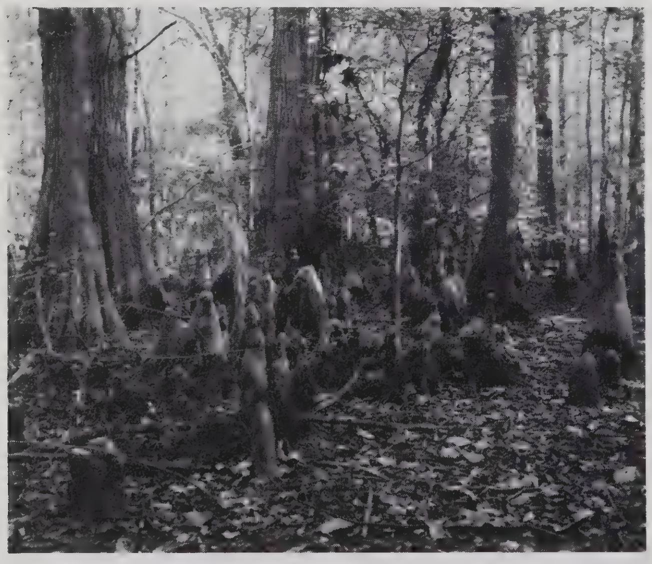

Fig. 40.—Cypress swamp in the Cache River bottomland. The "knees" grow up to 7 feet tall and tend to surround the bald cypress trees. This picture was taken during the dry season.

The forest trees of the bluff include hard maple, black walnut, hickories, sweet gum, mulberry, and papaw. Poison ivy is the most abundant shrub under the forest canopy, but wild hydrangea and spicebush are frequently seen there. Buttonbush is found at the base of the bluff. The herbaceous flora of the bluff is rich in species. Numerous grasses, sedges, and ferns grow on the stony slope. In the vicinity of the spring at the base of the bluff, clearweed, wild hydrangea, false nettle, and touch-me-not are common.

At the border of the swamp and bluff base, several plants of the rare spider lily grow under the soft maples and American elms. In the swamp the bald cypress grows abundantly and the pneumatophores are very common on the swamp floor. Associated with the bald cypress are big shellbark hickory, Drummond's maple, swamp cottonwood, overcup oak, and other trees. Common vines in this area are catbird grape and trumpet creeper. Erect shrubs include swamp privet, buttonbush, Virginia willow, and swamp rose.

Not all of this swamp floor supports an herbaceous vegetation, but where the herbs grow can be found ditch stonecrop, lizard's-tail, skullcap, and the beautiful, deep red cardinal flower. Among these are scattered plants of *Asclepias perennis.* A most unusual plant in this swamp is American featherfoil (Fig. 41), which was observed on May 2 and 6, 1969, in large numbers. On the first date it was also seen in smaller quantity in a swamp northwest of Vienna. The associations of plants on the decaying logs (Fig. 42) are similar to those in the Karnak swamp.

The third swamp, generally known as Heron Pond, lies in the low floodplain of the Cache River about 1 mile northwest of Forman in Johnson County. It has been studied recently by Anderson & White (1970). It is a larger swamp than that southwest of Forman and contains about 200 acres that are covered with water throughout the year. The Heron Pond area was relatively inaccessible because of the low bottomland and streams without bridges although a road and paths are now available. Earlier logging activities of man in parts of the area and changes in water level caused by beaver dams produced variations in the swamp community.

Bald cypress is the dominant tree of the swamp community. Tupelo is especially abundant in the recently cutover area. Drummond's maple grows on the rotten logs in the swamp and is also rooted in soil in the swamp border, where dogwoods, oaks, and slippery elms thrive. Buttonbush, swamp rose, snowbell, and Virginia willow are the common shrubs of the swamp; marsh St. John's-wort is a common herb.

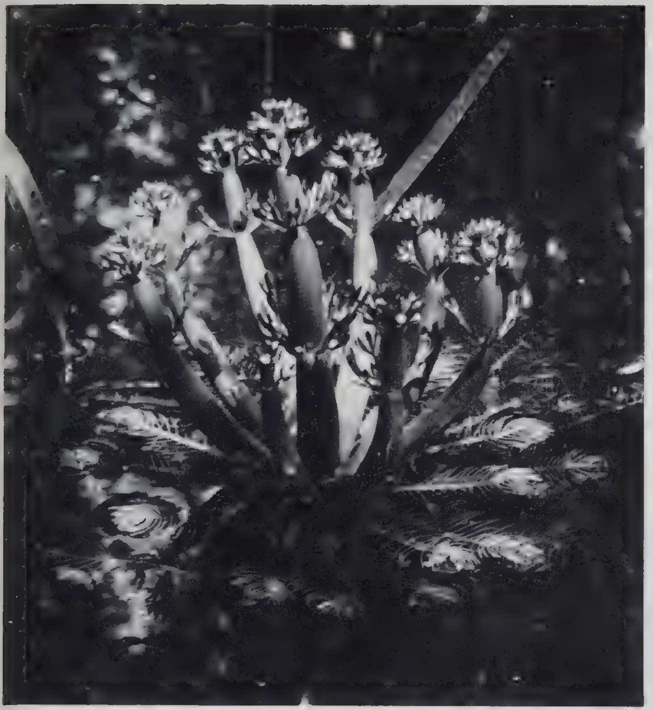

Fig. 41.—In Illinois, American featherfoil is restricted to the quiet water of the swamps in Jackson, Union, Johnson, and Pope counties. It is endangered because of habitat destruction in these counties.

In places duckweeds and mosquito fern float on the surface of the water.

A floodplain forest grows on slightly higher ground. Arboreous species such as big shellbark and shagbark hickories, mockernut, southern red oak, Shumard's oak, swamp chestnut oak, white oak, sweet gum, and catalpa grow here. Spicebush, possumhaw, hop hornbeam, blue beech, and poison ivy are present in the understory.

The bluffs to the north are mostly forested on the basal slopes by sweet gum, tulip tree, and such oaks as Shumard's, white, and northern red. Spicebush is the understory plant. Higher up the slope the forest contains white ash, hard maple, and Hercules' club. A hill prairie occupies one of the stony, southwest-facing slopes of the bluffs.

These three bald cypress swamps provide habitats for a number of interesting and unusual animals. In the swamps themselves are the banded pygmy sunfish and other fishes and crayfishes normally found in more southern states. *Cambarellus puer* and *Procambarus viaeviridis,* two crayfishes only recently discovered in Illinois (Page & Burr 1973:51), are common in the heavily vegetated parts of the swamp.

Amphibians and reptiles that are rare in Illinois but common in the swamps of the Cache River include the marbled salamander, mole salamander, cave salamander, bird-voiced treefrog, green treefrog, and cottonmouth. Unusual birds in the swamps are Swainson's warbler and the yellow-throated warbler.

Fig. 42.—A decaying log on the floor of a Cache River cypress swamp. An interesting association of plants grows on such logs, which are afloat during wet seasons and grounded during dry periods.

The distinctiveness of the fauna in the Cache River swamps is demonstrated by the numerous insects cited as unique or nearly unique in Illinois to these swamps. These insects include a rare grasshopper, *Inscudderia taxodii,* living on cypress trees; the mosquito, *Aedes aurifer,* for which these swamps are the only Illinois locality; rare plant bugs, *Ceratocapsus taxodii* and *Phytocoris purvus*; and the leafhopper, *Chlorotettix dentatus,* recorded in Illinois only from the Cache River swamps.

The first two swamps described here are in private ownership. The third, the Heron Pond area, is owned by the Illinois Department of Conservation and has been dedicated as the Heron Pond Nature Preserve of the Illinois Nature Preserve System. The Nature Conservancy has purchased much of the area near Heron Pond known as Little Black Slough and has transferred its holdings to the Department of Conservation. This purchase insures the preservation of a sizable acreage of cypress swamp in Illinois.

28. THORNTON'S RAVINE

Thornton's Ravine, located along the Ohio River about 5 miles downstream from Metropolis, or slightly more than 2 miles upstream from Joppa, in Massac County, occupies parts of sections 19, 20, 29, and 30, T. 15 S., R. 4 E., but can no longer be considered an unusual natural area. During the middle 1960's, logging was carried out and left a tangle of stumps, slash, brush, and even some felled but abandoned trees. The new owner had all this debris removed by a special machine. When the senior author visited the area on June 4, 1970, he found the slopes more or less intact but the floor of the ravine cleared of its cover.

Perhaps in a quarter century this area, if left to develop naturally, will again be of interest.

29. JACKSON HOLLOW

Jackson Hollow, Pope County, occupies about 320 acres in section 31, T. 11 S., R. 5 E., and in section 6, T. 12 S., R. 5 E., to the west of Little Bay Creek and a section of the Illinois Central Gulf Railroad, the section that is commonly called the Edgewood cutoff.

Much of the beauty of Jackson Hollow, like that of so many other beautiful sites in southern Illinois, results from the tall cliffs and the numerous, adjacent rock blocks that strew the slopes from the cliffs to the creeks. The cliffs and blocks are sandstone. Below the sandstone, in some places, layers of coal and shale are exposed. The sandstone is subjected to erosion by water, and, in those places where streams of water flow at the cliff bases or cascade over the cliffs, huge undercuts, locally called caves, have been formed by the breaking away of large masses of rock (Fig. 43). The small creeks in Jackson Hollow flow across beds or fragments of sandstone or beds of gravel or sand and, near Little Bay Creek, through deposits of silt.

The vegetation of Jackson Hollow falls into two main types, grassland and forest. Grassland is restricted to small prairie openings, most of them above the cliffs, and to fields of broomsedge that developed on abandoned farmland. Forests are represented by the mesic type; with beech, hard maple, and tulip tree, and by the xeric type, with certain oaks and hickories. The former type occupies the spaces below the cliffs, the latter the dry, stony slopes above the cliffs. Smooth alder, river birch, blue beech, and willows thrive along the streams, especially on the banks of Little Bay Creek at the mouth of Jackson Hollow. Farkle-

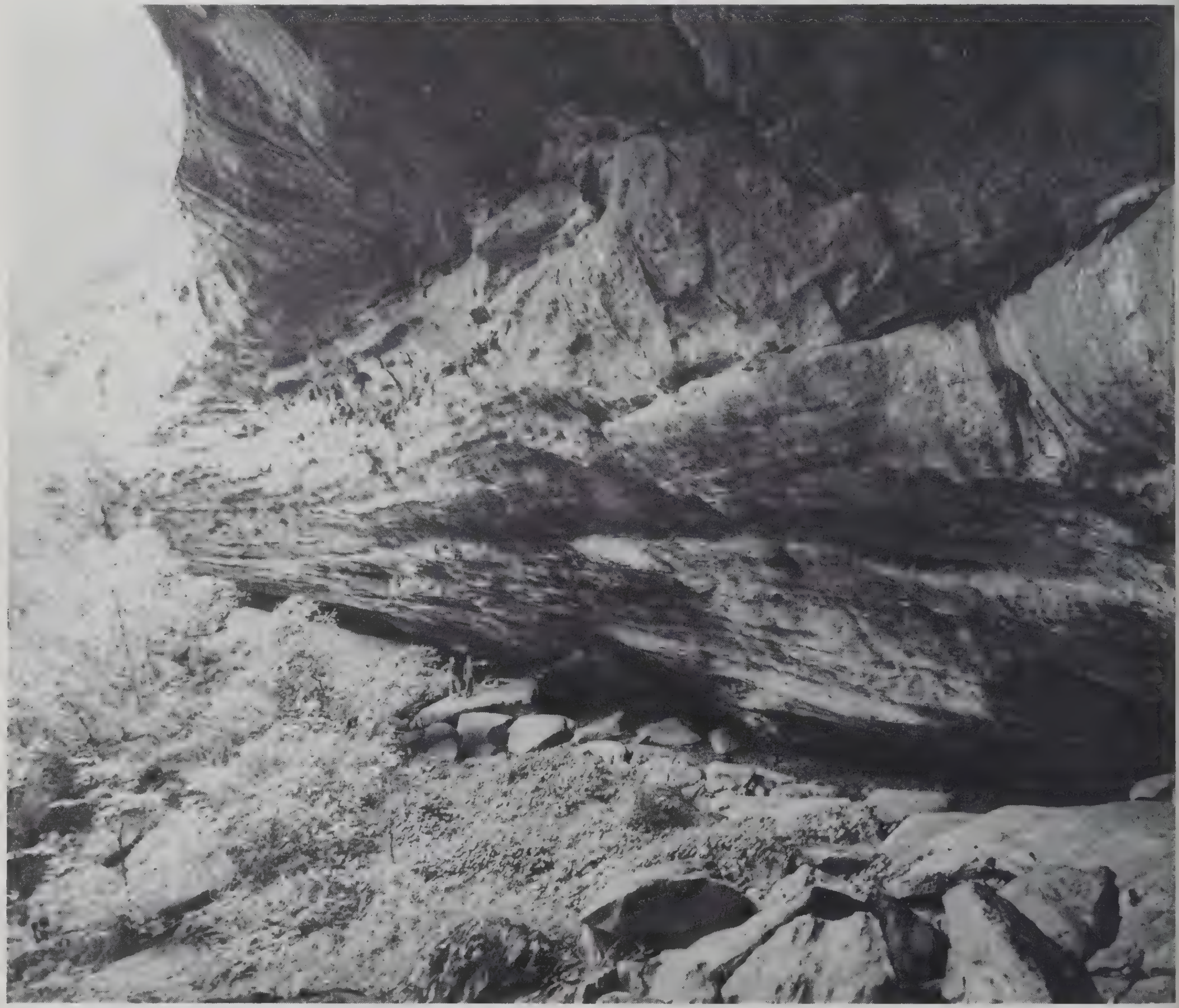

Fig. 43.—A huge undercut in Jackson Hollow, Pope County. Filmy fern grows at the back of this undercut. The two figures near the center serve as a scale to determine size.

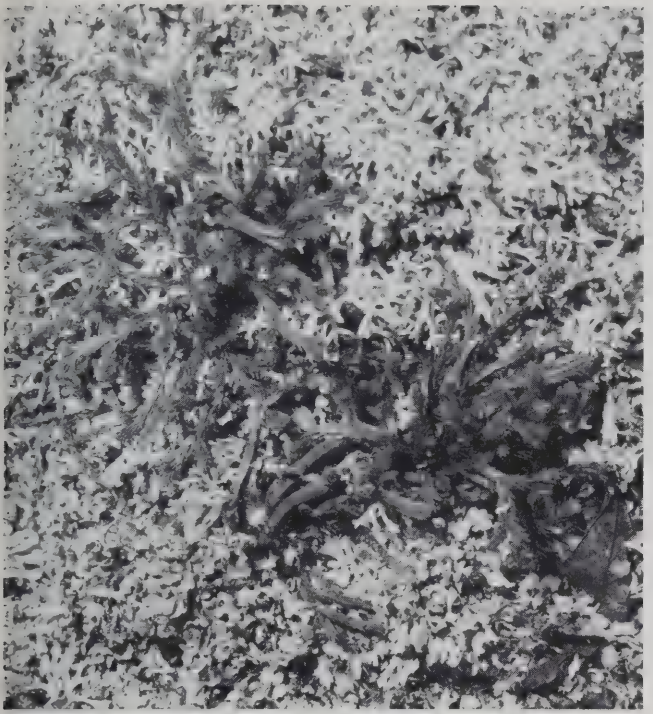

Fig. 44.—Rock selaginella growing in a mass of lichens. This species grows on sandstone in southern Illinois and also in sand prairie in central and northern Illinois.

berry is a common shrub on the stony slopes above the cliffs. The sandstone ledges support numerous lichens, some grasses, and innumerable patches of the moss, *Grimmia,* which when wet are deep green but when dry are almost black.

Many unusual plants occur in Jackson Hollow. The first collection in Illinois of the orchid, *Tipularia discolor,* was made here and cited by Mohlenbrock & Voigt (1959). The first collection of filmy fern in Illinois was made in this locality by Dr. Mary M. Steagall of Southern Illinois University, August 2, 1923. The fern was reported to grow in two of the numerous undercuts in the sandstone cliffs. On April 8, 1963, Dr. Warren H. Wagner, Jr., professor of botany, University of Michigan, accompanied R. A. Evers to Jackson Hollow, and he discovered a third stand in a cleft in one of the cliffs. On May 13, 1963, Evers found a fourth stand in an undercut.

The club moss, *Lycopodium lucidulum,* grows on a flat sandstone surface in one moist ravine, and rattlesnake plantain grows nearby. Professor Wagner and Evers found another club moss, *L. porophilum,* on one of the sandstone cliff faces. A number of orchids, including puttyroot, grow scattered throughout. Indian pipe and beech-drops are not rare here. Above the cliffs, rock selaginella (Fig. 44) and talinum thrive in scattered patches.

The vertebrate fauna of Jackson Hollow is rich and typical of that occupying the Shawnee Hills physiographic province. Of the invertebrate animals, one insect is of special interest and importance; it is the staphylinid beetle, *Stictocranius puncticeps,* an eastern species found here but apparently nowhere else in Illinois.

Presently Jackson Hollow is owned by the federal government and is under the control of the U. S. Forest Service.

30. BELL SMITH SPRINGS

Several miles east of Jackson Hollow is another of the numerous beauty spots of southern Illinois—Bell Smith Springs Recreational Area. It lies southeast of the community known as McCormick in Pope County. Within the area, Spring Branch, Hunting Branch, and Hill Branch enter Bay Creek, which then flows southward. Most of the area is in sections 33 and 34, T. 11 S., R. 5 E.

The huge cliffs and the small-to-massive blocks that strew the slopes between the cliffs and streams are sandstone. The cliffs have numerous undercuts, and a large natural bridge is developing along Bay Creek north of Spring Branch. Many years ago, Hill Branch cut into the sandstone and at one place formed a sizable gorge (Fig. 45). Beyond the gorge, downstream, the bed of Hill Branch is strewn with rock fragments. The beds of Hunting and Spring branches are of similar aspect. In some places the streams are shallow and have riffles or small falls; in other places they are deep and form quiet pools. Visitors use some of the large, deep, quiet pools as swimming holes (Fig. 1).

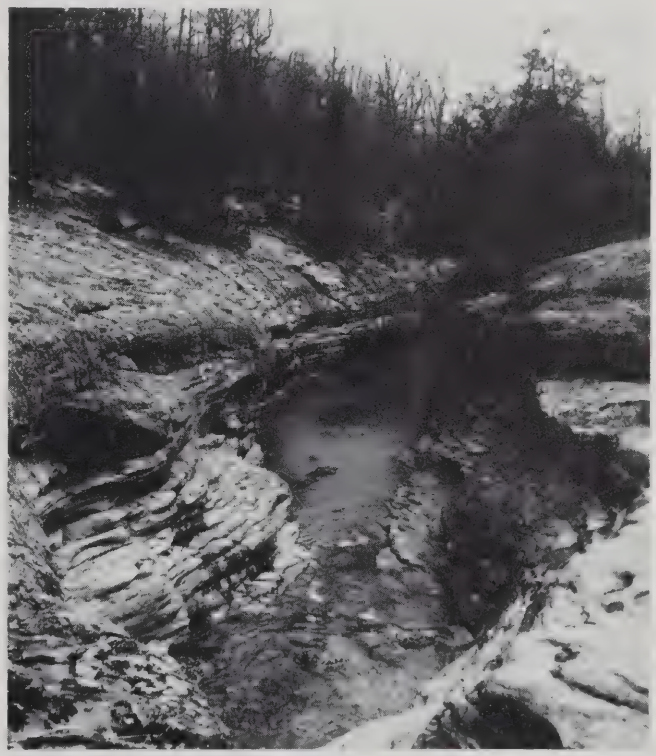

Fig. 45.—A gorge cut into the sandstone along Hill Branch at Bell Smith Springs, Pope County. The steep upper slopes are in many places covered with mosses and lichens.

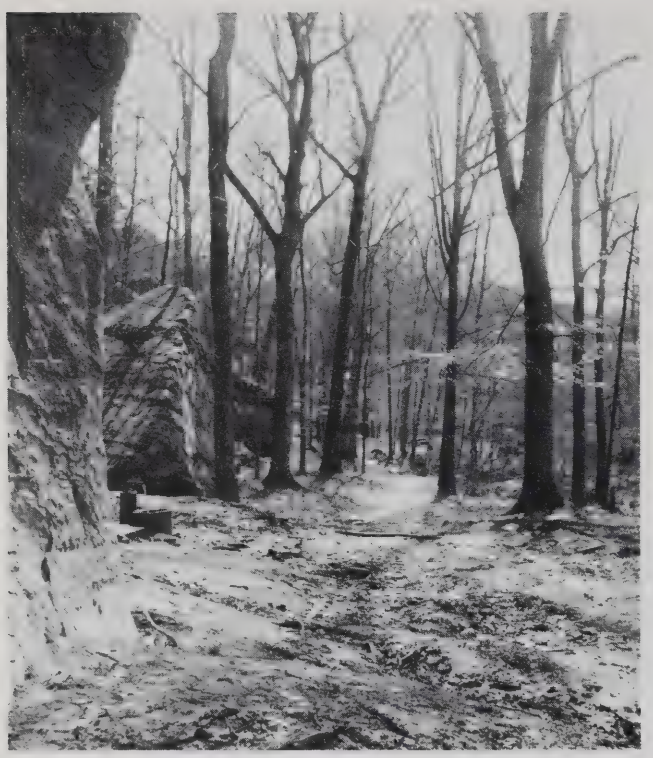

Fig. 46.—A beech-maple forest between the sandstone cliff and Bay Creek at Bell Smith Springs. This path leads the visitor to the natural bridge.

The vegetation of Bell Smith Springs is deciduous forest with prairie openings. Rock ledges and cliffs provide interesting plant habitats (Winterringer & Vestal 1956). A mesic forest, with beech and hard maple as the most common species, occupies the stream valleys (Fig. 46). Above the cliffs several species of oak and hickory replace the beech and maple. Along the stream banks the red maple, river birch, smooth alder, and Virginia willow thrive. Spicebush is a common shrub in the valley forest; farkleberry is common in the dry forests above the cliffs. Mosses, liverworts, and lichens clothe many of the moist, shaded overhangs. Some cliff faces lack plants and some support growths of lichens and a few ferns. A few hardy composites thrive in some of the cliff recesses. Some rock ledges are bare, but most are clothed with lichens and bryophytes. Vascular plants grow in crevices of the ledges or in the small pockets of soil that accumulate on the surface of the rock. In one overhang the filmy fern grows in scattered patches.

Students from Southern Illinois University have completed a botanical study of this area (Mohlenbrock 1968).

A very interesting insect, originally described from Illinois, lives on the dryer, lichen-covered sandstone ledges. It is the lichen grasshopper or lichen locust, *Trimerotropis saxatilis,* (Fig. 47). The coloration of this insect is such that it blends with the grayish-green lichens and the blackened sandstone.

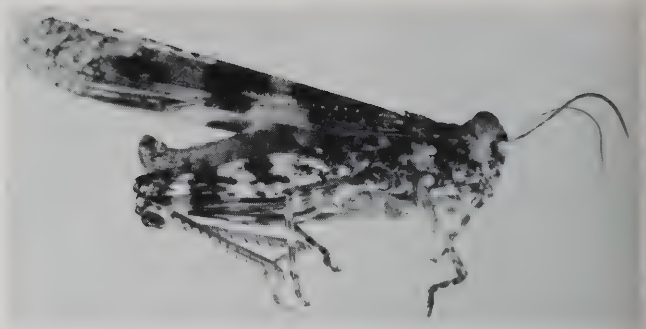

Fig. 47.—The lichen grasshopper, an insect with a pigmentation pattern enabling it to blend in closely with the lichens on which it lives.

The ravines, slopes, and streams harbor the rich and varied fauna characteristic of the Shawnee Hills. In the streams are two especially interesting animals, the stripetail darter and a crayfish, *Orconectes illinoiensis* (Fig. 48). The stripetail darter is distributed mainly in rocky streams in Kentucky and Tennessee and in Illinois is limited to the clear rocky streams in the Shawnee Hills. The crayfish is endemic to the Shawnee Hills. Bell Smith Springs is the only Illinois locality for two species of thrips, *Hoplothrips terminalis* and *Liothrips brevicornis.*

This area, under the control of the U. S. Forest Service, is used to some extent as a picnic area. The name is sometimes spelled "Belle Smith Spring," and for many years the name so spelled was carved on the Forest Service sign at the entrance. According to Allen (1949), the name should be Bell Smith.

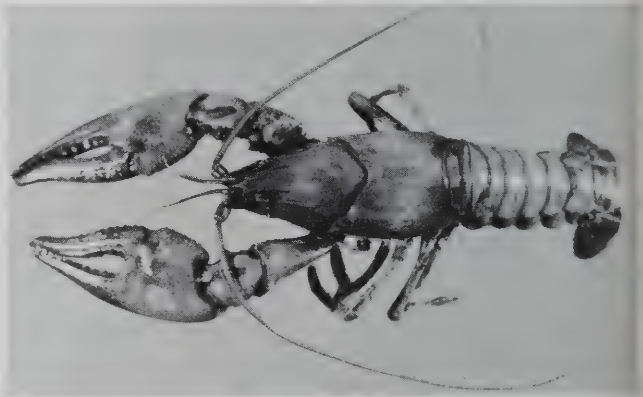

Fig. 48.—*Orconectes illinoiensis,* a crayfish endemic to rocky streams of the Shawnee Hills.

31. HAYES CREEK CANYON

Hayes Creek Canyon, less than a mile north of Eddyville, Pope County, occupies part of section 31, T. 11 S., R. 6 E., and part of section 6, T. 12 S., R. 6 E. In this locality, Hayes Creek flows southward over beds of sandstone. A tributary stream from the east flows over similar beds and has cut a steep gorge at the escarpment (Fig. 49). Some distance below the escarpment this tributary joins Hayes Creek, which then flows southwestward.

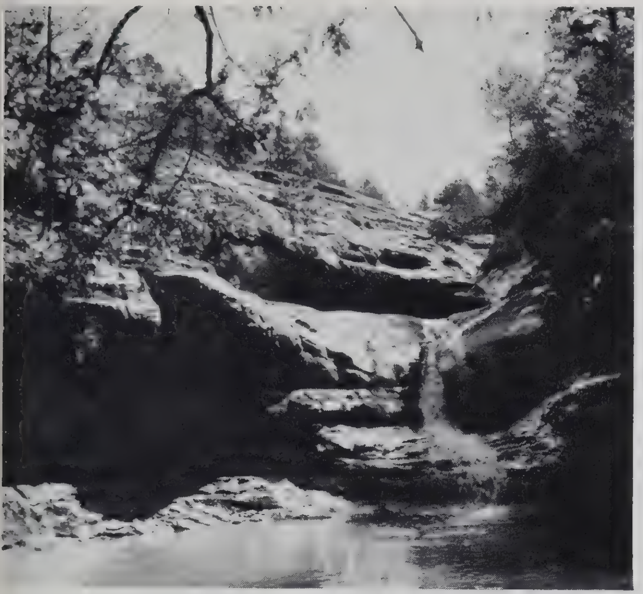

Fig. 49.—The gorge of a tributary stream at Hayes Creek Canyon, north of Eddyville, Pope County.

The types of vegetation at Hayes Creek Canyon are similar to those at Bell Smith Springs. Rock selaginella and *Selaginella apoda* (Fig. 50) grow on the sandstone, and the filmy fern grows in two stations about one-fourth mile apart. Christmas fern, common wood fern, and common polypody are the abundant ferns in this area. Twayblade grows in the moist woods along the stream.

Among the unusual animals in Hayes Creek Canyon and the nearby area are a rare thrips, *Heterothrips quercicola*; a crayfish endemic to the Shawnee Hills, *Orconectes illinoiensis* (Fig 48); and the fishes, cypress darter and stripetail darter. The cypress darter is found in only three streams in Illinois.

An excellent nature trail could be constructed from Ozark, Johnson County, eastward through Camp Packentuck (now a part of Camp Ondessonk), Jackson Hollow, Bell Smith Springs, through Spring Branch to Cedar Grove Church, and eastward past Cedar Head to Hayes Creek Canyon and Lusk Creek.

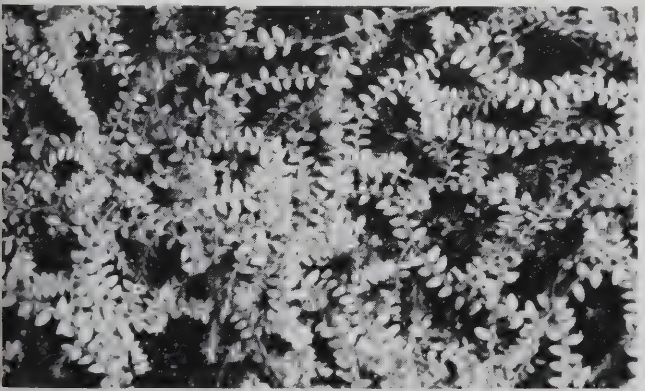

Fig. 50.—A selaginella, *Selaginella apoda*, which grows on the moist sandstone of Hayes Creek Canyon.

Hikers should have a scenic trail over hills and through valleys in southern Illinois.

32. LUSK CREEK CANYON

Lusk Creek Canyon, also known as Lusk Creek Gorge, is the most beautiful stream valley in southern Illinois and perhaps in the entire state. Lusk Creek drains much of northeastern Pope County. Its source is near Delwood, a small community on Illinois highway 145. As the creek flows southward, it is joined by numerous tributary streams and finally empties into the Ohio River at Golconda. The locality of special interest is the valley of Lusk Creek as it passes through sections 33 and 34, T. 11 S., R. 6 E., about 2.5 miles east and 1.5–2.0 miles north of Eddyville.

In this locality Lusk Creek has cut through the massive sandstone, carving a valley, canyon, or gorge with cliffs that vary from only a few feet to almost 100 feet high. In some places the valley floor is moderately wide and the bluffs of the stream have steep toe slopes beneath the cliffs. In a few places there is no valley floor except that which the creek occupies. The creek in some areas is shallow and flows swiftly around numerous rocks and over riffles; in others it is deep and forms quiet pools. A canyon in section 34 is hairpin- or horseshoe-shaped. The cutbank of this canyon or gorge is a towering, vertical sandstone cliff almost devoid of vegetation (Fig. 51). The slip slope—the slope opposite the cutbank—is not vertical but rather a steep sandstone slope that is clothed with mosses, lichens, and deciduous trees. Near the top of the canyon wall is the Indian Kitchen. The summit of the ridge, the area within the horseshoe, is quite rocky; the sandstone is exposed as large ledges, with only a few large blocks near the cliff tops.

Upstream from this beautiful gorge, Lusk Creek flows between steep cliffs, and within 0.5 mile it makes a right-angle bend. At this point Bear Creek joins Lusk Creek. The cliffs along Bear Creek are tall at this junction but decrease in height upstream and finally disappear as the creek flows over the upper surface of the sandstone escarpment. The cliffs along Lusk Creek, upstream from the Bear Creek junction, are quite tall; approximately 0.5 mile north of the junction they reach a height that is tremendous for Illinois.

Above the cliffs of Lusk Creek are slopes of varying steepness. The less steep slopes were cultivated in earlier days but now are deserted fields or have been converted into pine plantations. Some prairie plants thrive in the deserted fields. The upland above Indian Kitchen and within the horseshoe supports a xeric forest, with red cedar, black-jack oak, and farkleberry as common plants.

Deciduous forest covers the toe slopes of the bluffs. Beech, hard maple, red maple, river birch, alder, and sycamore grow near the stream, oaks and

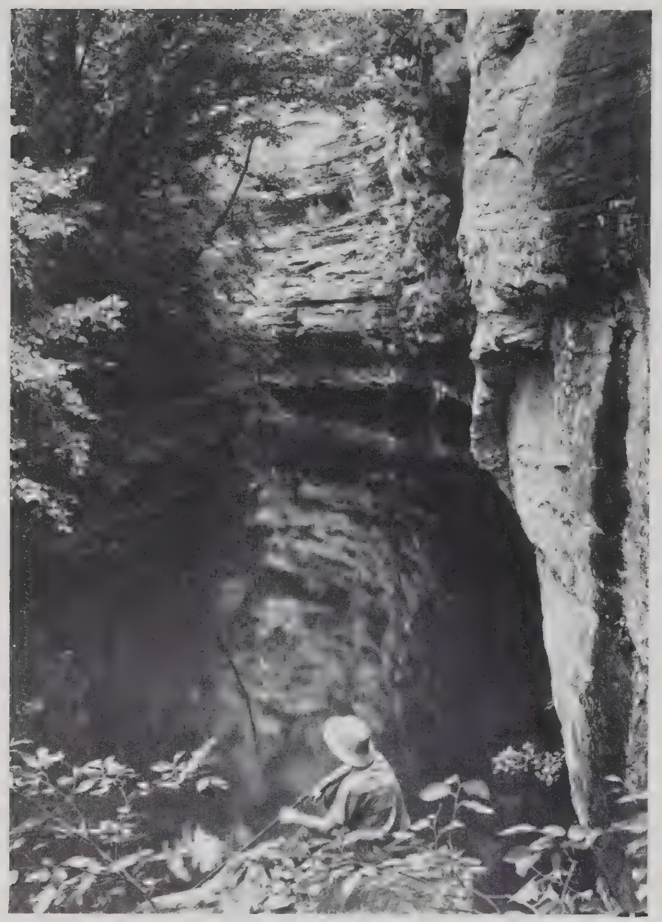

Fig. 51.—The deep gorge along Lusk Creek, northeast of Eddyville, Pope County. The cliff supports little plant life; the slip slope is covered with mosses, lichens, and some trees.

hickories higher up the slopes. The cliffs vary from extremely dry and lacking plant life to very moist and abounding in mosses, liverworts, lichens, and small herbaceous plants, including asters and goldenrods. On one of these cliffs the club moss, *Lycopodium complanatum* var. *flabelliforme,* (Fig. 52) grows. Partridge berry and sphagnum moss are not uncommon on the moist cliffs.

In the springtime the abundant flowers of the shadbush and flowering dogwood create a beautiful sight. And here in autumn the pastel colors of the oak leaves on the upper slopes, most beautiful and restful to the eyes of the observer, provide a never-to-be-forgotten experience. The lichens, bryophytes, ferns, and fern allies have been studied by Skorepa & Snider (1967).

In the area of Lusk Creek can be seen the pileated woodpecker. Turkey vultures apparently nest in the recesses of the tall cliffs north of the junction of Lusk Creek with Bear Creek. White-tailed deer are abundant here, as they are in many other parts of southern Illinois.

Lusk Creek was described by Smith (1971:7) as an outstanding Illinois stream with rocky pools, gravelly riffles, and cold springs. Among the unusual fishes of Lusk Creek are the black redhorse, spottail darter, stripetail darter, and mimic shiner. The bird fauna of the area is quite diverse, with the hooded warbler and chuck-will's-widow being especially interesting because of their rarity in Illinois.

Some of the unusual invertebrates inhabiting the Lusk Creek area are the amphipods, *Crangonyx anomalus* and *Synurella dentata,* the former known in Illinois only from the Lusk Creek drainage; the crayfish, *Orconectes illinoiensis* (Fig. 48), an endemic of the Shawnee Hills; a rare stonefly, *Isoperla burksi*; two rare mayflies, *Stenonema pudicum* and *Pseudocloeon myrsum*; and the butterfly, Bell's roadside skipper, *Amblyscirtes belli,* known in Illinois only from the Lusk Creek area.

Most of the Lusk Creek Canyon area is a part of the Shawnee National Forest. A small part is owned by the Illinois Department of Conservation and is a dedicated preserve in the Illinois system.

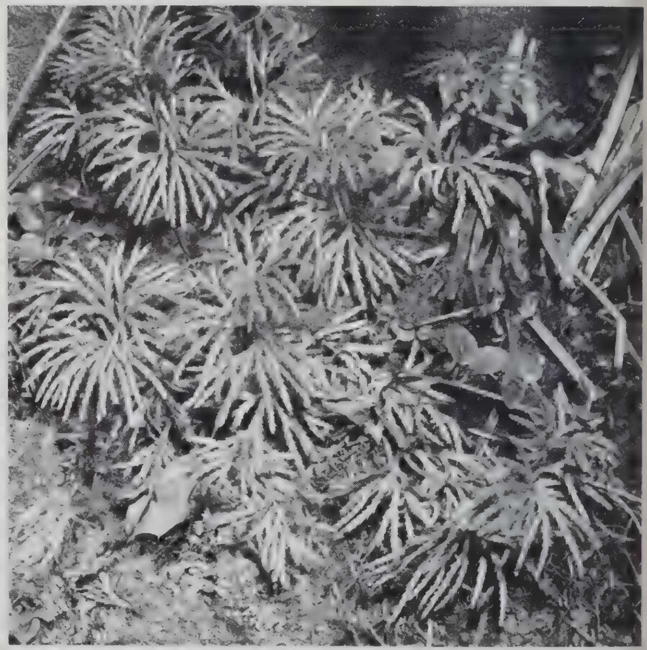

Fig. 52.—The club moss, *Lycopodium complanatum* var. *flabelliforme,* on a bluff bordering Lusk Creek.

33. BIG CREEK

Big Creek is a beautiful, clear, rocky, spring-fed stream draining limestone formations in western Hardin County. The stream system is mostly between Karbers Ridge and Elizabethtown and is composed of three main tributaries: Big Creek proper (Fig. 53), Hogthief Creek, and Goose Creek. All three tributaries have large influxes of spring water, upstream substrates of slab stones, and downstream substrates of gravel and rock. The hilly scenery and the biota of Big Creek are near facsimilies of those of some Appalachian streams of Kentucky and Ten-

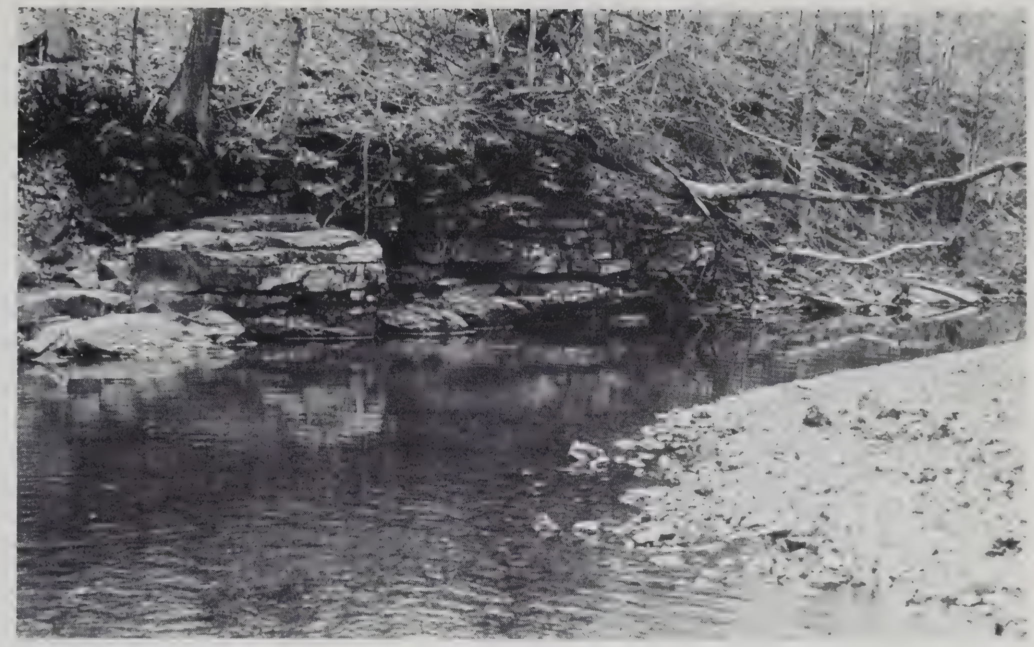

Fig. 53.—Big Creek in Hardin County, a rocky spring-fed stream supporting populations of many unusual animals.

nessee. Smith (1971:7) considered Big Creek to be the outstanding stream in southeastern Illinois.

The stream has populations of three rare crayfishes, relict populations of northern fishes, and several other fishes with very limited distributions in Illinois. These organisms inhabit Big Creek because of its unique characteristics, most notably the large influx of spring water and the preponderance of rocky substrates.

Among the animals in Big Creek of special interest are the crayfishes, *Orconectes placidus,* known in Illinois only from Big Creek, *Orconectes kentuckiensis,* a rare crayfish found in Illinois only in Big Creek and nearby Peters Creek, and *Cambarus laevis,* restricted in Illinois to a few spring-fed streams.

The fishes of special interest are the stripetail and spottail darters, rock bass, smallmouth bass, northern hog sucker, black redhorse, least brook lamprey (known in Illinois from only two streams), and the spring cavefish (Fig. 54), known in Illinois from only two other areas.

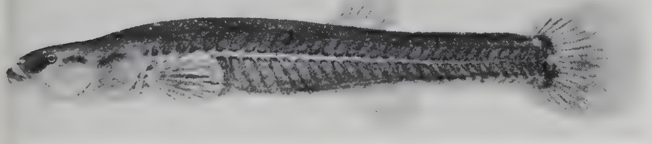

Fig. 54.—Spring cavefish, a rare fish limited in distribution in Illinois to a few springs in the extreme southern part of the state.

Most of the stream system is forested although clearing for agricultural purposes has eliminated wildlife habitats from some rather large areas. Winding gravel roads transect the stream system at many points and provide a particularly interesting drive. A historic attraction on the watershed is Illinois Furnace, the site of an early iron works in Illinois. Illinois Furnace is approximately 3 miles north of Elizabethtown and is marked on most maps.

The rare pseudoscorpion, *Heterochthonius multispinosus,* and the rare plant bug, *Lygocoris tinctus,* are among the unusual animals of Big Creek.

Much of Big Creek is federally owned and is managed by the U. S. Forest Service. Even so, Big Creek is at present under serious threat of overdevelopment. The stream banks are being cleared of trees at various points, and in all likelihood this will result in a raising of the water temperature, because of reduced shading, and in the extirpation of those species in Big Creek dependent on the cool-water environment.

The populations in Big Creek of animals rare elsewhere in Illinois have led to the selection of the stream as a site for several life-history studies. Studies on the crayfishes are now in progress by personnel of the Illinois Natural History Survey, and studies on the spottail darter and stripetail darter have already been completed (Page 1974 and 1975).

RECAPITULATION

These and other natural areas of our state are of great value to scientists of Illinois and elsewhere. To others these natural areas are also of value. Although most persons will never carry out biological studies, the natural areas offer them opportunities to see bits of the forests and prairies for which Illinois was once famous and to observe the plants and animals, both common and rare, in some of these interesting habitats. It is in these places that they can relax and listen to the sounds of nature. Many persons receive a lift from such relaxations. In our society, which requires a rapid pace but also provides much leisure time, these individuals deserve consideration. The observers of nature should be provided with places where they can enjoy their leisure hours and where they can relax, just as others have been provided with hunting, fishing, boating, and playground areas.

We have attempted to take you very quickly through 33 natural or scientific areas of Illinois by means of descriptions and photographs. We hope that this vicarious journey may arouse an ardent desire in you to visit these localities, at least the ones nearest home. Enjoy yourselves in these places. Help preserve them for future generations.

LITERATURE CITED

ALLEN, JOHN W. 1949. Pope County notes. Southern Illinois University Museum of Natural and Social Science Contribution 22. 95 p.

ANDERSON, ROGER C., and JOHN WHITE. 1970. A cypress swamp outlier in southern Illinois. Illinois State Academy of Science Transactions 63 (1) :6–13.

ARTIST, RUSSELL C. 1936. Stratigraphy and preliminary pollen analysis of a Lake County, Illinois, bog. Butler University Botanical Studies 3 (13) :191–198.

ASHBY, WILLIAM C., and JAMES E. OZMENT. 1967. Plant species of Beall's woods, Wabash County, Illinois. Illinois State Academy of Science Transactions 60 (2) :174–183.

BAKER, FRANK COLLINS. 1922. The molluscan fauna of the Big Vermilion River, Illinois. Illinois Biological Monographs 7 (2) :3–126.

———. 1939. Fieldbook of Illinois land snails. State of Illinois, Natural History Survey Division, Urbana. 166 p.

BENKE, H. C. 1932*a*. Trout Park "wonderland" is revealed. Elgin Courier-News, 29 March:1–2.

———. 1932*b*. More of park flora is listed. Elgin Courier-News, 30 March:2.

BETZ, ROBERT F., and MARION H. COLE. 1969. The Peacock Prairie—a study of a virgin Illinois mesic black-soil prairie forty years after initial study. Illinois State Academy of Science Transactions 62 (1) :44–53.

BIRKENHOLZ, DALE E. 1975. The summer birds of Goose Lake Prairie Nature Preserve, 1970–1973. Chicago Academy of Sciences Natural History Miscellanea 193. 11 p.

BOEWE, G. H., STELLA HOLMES BARRICK, and STELLA M. HAGUE. 1935. Mosses from Apple River Canyon, Mississippi Palisades and White Pines Forest state parks. Illinois State Academy of Science Transactions 28 (2) :83–84.

BOYD, JOHN A., BROOKS M. BURR, LAWRENCE M. PAGE, and PHILIP W. SMITH. [1975.] A study of threatened and/or unique fishes within the boundaries of the Shawnee National Forest of southern Illinois. Pages 1–20 *in* Those on the brink of doom: a study of rare fishes in the Shawnee National Forest. U.S. Department of Agriculture Forest Service Publication.

BRETZ, J. HARLEN, and S. E. HARRIS, JR. 1961. Caves of Illinois. Illinois State Geological Survey Report of Investigations 215. 87 p.

BURKS, B. D. 1953. The mayflies, or Ephemeroptera, of Illinois. Illinois Natural History Survey Bulletin 26 (1) :1–216.

CAMPBELL, D., F. SWINK, J. SCHWEGMAN, R. SCHULENBERG, and R. BETZ. 1970. Plants of the Goose Lake prairie. 4 p. Mimeographed.

COLE, GERALD A. 1970. *Gammarus minus:* geographic variation and description of new subspecies *G. m. pinicollis* (Crustacea, Amphipoda). American Microscopical Society Transactions 89 (4) :514–523.

DELONG, D. M. 1948. The leafhoppers, or Cicadellidae, of Illinois (Eurymelinae-Balcluthinae). Illinois Natural History Survey Bulletin 24 (2) :97–376.

DITMARS, RAYMOND L. 1937. Snakes of the world. The Macmillan Company, New York. 207 p. + 84 plates.

EBINGER, J. E., and H. M. PARKER. 1969. Vegetation survey of an oak-hickory maple forest in Clark County, Illinois. Illinois State Academy of Science Transactions 62 (4) :379–387.

EVERS, ROBERT A. 1950. Notes on the Illinois flora. American Midland Naturalist 44 (3) :617–621.

———. 1951. Four plants new to the Illinois flora. Rhodora 53 (628) :111–113.

———. 1955. Hill prairies of Illinois. Illinois Natural History Survey Bulletin 26 (5) :367–446.

———. 1961. The filmy fern in Illinois. Illinois Natural History Survey Biological Notes 44. 16 p.

———. 1963. Some unusual natural areas in Illinois and a few of their plants. Illinois Natural History Survey Biological Notes 50. 32 p.

FRISON, THEODORE H. 1935. The stoneflies, or Plecoptera, of Illinois. Illinois Natural History Survey Bulletin 20 (4) :281–471.

———. 1942. Studies of North American Plecoptera, with special reference to the fauna of Illinois. Illinois Natural History Survey Bulletin 22 (2) :235–355.

FULLER, GEORGE D. 1946. A check list of the vascular plants of Jo Daviess County, Illinois. Illinois State Academy of Science Transactions 38:51–63.

GATES, FRANK CALEB. 1912. The vegetation of the beach area in northeastern Illinois and southeastern Wisconsin. Illinois State Laboratory of Natural History Bulletin 9 (5) :255–372 + 20 plates.

GLEASON, HENRY ALLAN. 1910. The vegetation of the inland sand deposits of Illinois. Illinois State Laboratory of Natural History Bulletin 9 (3) :23–174 + 20 plates.

GRABER, JEAN W., and RICHARD R. GRABER. 1973. Nesting distribution of the veery in Illinois. Illinois Audubon Bulletin 1973 winter-spring (164) :50–52.

GRABER, RICHARD R., JEAN W. GRABER, and ETHELYN L. KIRK. 1972. Illinois birds: Hirundinidae. Illinois Natural History Survey Biological Notes 80. 36 p.

———, ———, and ———. 1974. Illinois birds: Tyrannidae. Illinois Natural History Survey Biological Notes 86. 56 p.

GUNNING, GERALD E., and WILLIAM M. LEWIS. 1955. The fish population of a spring-fed swamp in the Mississippi Bottoms of southern Illinois. Ecology 36 (4) :552–558.

HART, CHARLES A., and HENRY ALLAN GLEASON. 1907. On the biology of the sand areas of Illinois. Illinois State Laboratory of Natural History Bulletin 7 (7) :137–272 + 16 plates.

HEBARD, MORGAN. 1934. The Dermaptera and Orthoptera of Illinois. Illinois Natural History Survey Bulletin 20 (3) :125–279.

HELLINGA, GERALD A., and JOHN E. EBINGER. 1970. Additions to the flora of Clark County, Illinois, from the Rocky Branch Nature Preserve. Illinois State Academy of Science Transactions 63 (4) :392–396.

HOFF, C. CLAYTON. 1949. The pseudoscorpions of Illinois. Illinois Natural History Survey Bulletin 24 (4) :413–498.

HOTTES, FREDERICK C., and THEODORE H. FRISON. 1931. The plant lice, or Aphiidae, of Illinois. Illinois Natural History Survey Bulletin 19 (3) :123–447.

IRWIN, RODERICK R., and JOHN C. DOWNEY. 1973. Annotated checklist of the butterflies of Illinois. Illinois Natural History Survey Biological Notes 81. 60 p.

JOHNSON, WILLIAM WARREN. 1970. The resident mammal and bird populations of a sand prairie and forest near Bath, Illinois. Illinois State Academy of Science Transactions 63 (3) :234–239.

KLIMSTRA, W. D. 1969. Mammals of the Pine Hills-Wolf Lake-LaRue Swamp complex. Chicago Academy of Sciences Natural History Miscellanea 188. 10 p.

———, and J. L. Roseberry. 1969. Additional observations on some southern Illinois mammals. Illinois State Academy of Science Transactions 62 (4) :413–417.

Knight, Harry H. 1941. The plant bugs, or Miridae, of Illinois. Illinois Natural History Survey Bulletin 22 (1) :1–234.

Lopinot, A. C., and Philip W. Smith. 1973. Rare and endangered fish of Illinois. Illinois Department of Conservation Division of Fisheries, Springfield. 53 p.

Miller, Robert Rush. 1972. Threatened freshwater fishes of the United States. American Fisheries Society Transactions 101 (2) :239–252.

Mills, Harlow B. 1948. New North American Tomocerinae. Entomological Society of America Annals 41 (3) :353–359.

Minton, Sherman A., Jr., and Madge Rutherford Minton. 1969. Venomous reptiles. Charles Scribner's Sons, New York. 274 p.

Mohlenbrock, Robert H., ed. 1968. A floristics study of Bell Smith Springs, Pope County, Illinois. Illinois State Academy of Science Transactions 61 (1) :53–79.

———, and John W. Voigt. 1959. *Tipularia discolor* in Illinois. Taxonomic Index 22 (5) :xxxix–xl *in* Brittonia 11 (3) .

Morris, Michael A. 1974. An Illinois record for a triploid species of the *Ambystoma jeffersonianum* complex. Journal of Herpetology 8 (3) :255–256.

Necker, Walter L., and Donald M. Hatfield. 1941. Mammals of Illinois: an annotated check list with keys and bibliography. Chicago Academy of Sciences Bulletin 6 (3) :17–60.

Page, Lawrence M. 1974. The life history of the spottail darter, *Etheostoma squamiceps,* in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———. 1975. The life history of the stripetail darter, *Etheostoma kennicotti,* in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

———, and Brooks M. Burr. 1973. Distributional records for the crayfishes *Cambarellus puer, C. shufeldtii, Procambarus gracilis, P. viaeviridis, Orconectes lancifer, O. bisectus,* and *O. rusticus.* Kentucky Academy of Science Transactions 34: 51–52.

———, and Philip W. Smith. 1970. The life history of the dusky darter, *Percina sciera,* in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes 69. 15 p.

———, and ———. 1971. The life history of the slenderhead darter, *Percina phoxocephala,* in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes 74. 14 p.

Paintin, Ruth Davis. 1929. The morphology and nature of a prairie in Cook County, Illinois. Illinois State Academy of Science Transactions 21:152–157.

Parmalee, Paul W. 1967. The fresh-water mussels of Illinois. Illinois State Museum Popular Science Series 8. 108 p.

Pepoon, H. S. 1917. The primrose rocks of Illinois. Illinois State Academy of Science Transactions 10:159–162.

———. [1920.] A proposed new state park. Illinois State Academy of Science Transactions 12:64–68.

Reichle, David E. 1969. Distribution and abundance of bog-inhabiting pselaphid beetles. Illinois State Academy of Science Transactions 62 (3) :233–264.

Ross, Herbert H. 1944. The caddis flies, or Trichoptera, of Illinois. Illinois Natural History Survey Bulletin 23 (1) :1–326.

———. 1963. The dunesland heritage of Illinois. Illinois Natural History Survey Circular 49. 28 p.

———, and William R. Horsfall. 1965. A synopsis of the mosquitoes of Illinois (Diptera, Culicidae) . Illinois Natural History Survey Biological Notes 52. 50 p.

Rossman, Douglas A. 1960. Herpetofaunal survey of the Pine Hills area of southern Illinois. Florida Academy of Sciences Quarterly Journal 22 (4) :207–225.

Shelford, Victor E. 1911*a*. Ecological succession. I. Stream fishes and the method of physiographic analysis. Biological Bulletin 21 (1) :9–35.

———. 1911*b*. Ecological succession. II. Pond fishes. Biological Bulletin 21 (3) :127–151.

———. 1911*c*. Ecological succession. III. A reconnaissance of its causes in ponds with particular reference to fish. Biological Bulletin 22 (1) :1–38.

Sheviak, C. J., and Alan Haney. 1973. Ecological interpretations of the vegetation patterns of Volo Bog, Lake County, Illinois. Illinois State Academy of Science Transactions 66 (1–2) :99–112.

Skorepa, A. C., and Jerry A. Snider. 1967. Some unusual lower plants from Lusk Creek Canyon, Pope County, Illinois. Illinois State Academy of Science Transactions 60 (1) :105–106.

Smith, Philip W. 1961. The amphibians and reptiles of Illinois. Illinois Natural History Survey Bulletin 28 (1) :1–298.

———. 1965. A preliminary annotated list of the lampreys and fishes of Illinois. Illinois Natural History Survey Biological Notes 54. 12 p.

———. 1968. An assessment of changes in the fish fauna of two Illinois rivers and its bearing on their future. Illinois State Academy of Science Transactions 61 (1) :31–45.

———. 1971. Illinois streams: a classification based on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Natural History Survey Biological Notes 76. 14 p.

———, and Paul W. Parmalee. 1954. Notes on distribution and habits of some bats from Illinois. Kansas Academy of Science Transactions 57 (2) :200–205.

Stannard, Lewis J., Jr. 1958. The first records of *Boreus* (Boreidae, Mecoptera) in Illinois. Illinois State Academy of Science Transactions 50:279–280.

———. 1968. The thrips, or Thysanoptera, of Illinois. Illinois Natural History Survey Bulletin 29 (4) :215–552.

Stover, E. L. 1930. A mesophytic ravine ("Rocky Branch") : a floristic account. Eastern Illinois State Teachers College, Teachers College Bulletin 110. 26 p.

Vestal, Arthur G. 1913. An associational study of Illinois sand prairie. Illinois State Laboratory of Natural History Bulletin 10 (1) :1–96 + 5 plates.

———. 1914. A black-soil prairie station in northeastern Illinois. Torrey Botanical Club Bulletin 41:351–363.

Webb, Donald W., Norman D. Penny, and John C. Marlin. 1975. The Mecoptera, or scorpionflies, of Illinois. Illinois Natural History Survey Bulletin 31 (7) :251–316.

Winterringer, Glen S., and Arthur G. Vestal. 1956. Rock-ledge vegetation in southern Illinois. Ecological Monographs 26 (2) :105–130.

Zales, William M. 1971. Bryophytes of the Goose Lake prairie, Illinois. Illinois State Academy of Science Transactions 64 (3) :222–224.

SCIENTIFIC EQUIVALENTS OF COMMON NAMES OF PLANTS

Alder, smooth—*Alnus serrulata* (Ait.) Willd.
Arbor vitae—*Thuja occidentalis* L.
Arrow-grass—*Triglochin maritima* L.
T. palustris L.
Arrowhead, common—*Sagittaria latifolia* Willd.
Arrow-wood—*Viburnum dentatum* L.
Ash, blue—*Fraxinus quadrangulata* Michx.
Ash, prickly—*Zanthoxylum americanum* Mill.
Ash, wafer—*Ptelea trifoliata* L.
Ash, white—*Fraxinus americana* L.
Aspen, large-toothed—*Populus grandidentata* Michx.
Aspen, quaking—*Populus tremuloides* Michx.
Aster—*Aster* spp.
Aster, narrow-leaved—*Aster linariifolius* L.
Aster, azure—*Aster azureus* Lindley
Azalea, pink—*Rhododendron roseum* (Loisel.) Rehd.
Basswood—*Tilia americana* L.
Bearberry—*Arctostaphylos uva-ursi* (L.) Spreng.

Beard-tongue—*Penstemon* spp.
Bedstraw—*Galium* spp.
Beech—*Fagus grandifolia* Ehrh.
Beech, blue—*Carpinus caroliniana* Walt.
Beech-drops—*Epifagus virginiana* (L.) Bart.
Beggar-ticks—*Bidens* spp.
Birch, dwarf—*Betula pumila* L.
Birch, river—*Betula nigra* L.
Bittersweet, climbing—*Celastrus scandens* L.
Blackberry—*Rubus* spp.
Bladdernut—*Staphylea trifolia* L.
Bladder-pod—*Lesquerella ludoviciana* (Nutt.) Wats.
Blazing star—*Liatris aspera* Michx.
L. cylindracea Michx.
L. pycnostachya Michx.
Bloodleaf—*Iresine rhizomatosa* Standl.
Bloodroot—*Sanguinaria canadensis* L.
Blue-eyed grass—*Sisyrinchium albidum* Raf.
Bluegrass, Canada—*Poa compressa* L.
Bluegrass, Kentucky—*Poa pratensis* L.
Bluehearts—*Buchnera americana* L.
Blue-joint—*Calamagrostis canadensis* (Michx.) Nutt.
Bluestem, big—*Andropogon gerardi* Vitman
Bluestem, little—*Andropogon scoparius* Michx.
Box elder—*Acer negundo* L.
Broomsedge—*Andropogon virginicus* L.
Buckbean—*Menyanthes trifoliata* L.
Buckeye—*Aesculus glabra* Willd.
Buckthorn—*Rhamnus lanceolata* Pursh
Buckthorn, alder—*Rhamnus frangula* L.
Bulrush—*Scirpus* spp.
Bulrush, great—*Scirpus validus* Vahl
Bulrush, river—*Scirpus fluviatilis* (Torr.) Gray
Bulrush, tufted—*Scirpus cespitosus* L.
Bunchberry—*Cornus canadensis* L.
Bur-reed, giant—*Sparganium eurycarpum* Engelm.
Buttercup, white—*Ranunculus aquatilis* L.
Butternut—*Juglans cinerea* L.
Buttonbush—*Cephalanthus occidentalis* L.
Cabbage, skunk—*Symphlocarpus foetidus* (L.) Nutt.
Cardinal flower—*Lobelia cardinalis* L.
Catalpa—*Catalpa* spp.
Cattail—*Typha latifolia* L.
T. angustifolia L.
Cherry, wild black—*Prunus serotina* Ehrh.
Chokeberry—*Aronia melanocarpa* (Michx.) Ell.
Cinquefoil, purple—*Potentilla palustris* (L.) Scop.
Clearweed—*Pilea pumila* (L.) Gray
Cliff-brake—*Pellaea atropurpurea* (L.) Link
Clover, purple prairie—*Petalostemum purpureum* (Vent.) Rydb.
Clover, white prairie—*Petalostemum candidum* (Willd.) Michx.
Cocklebur—*Xanthium strumarium* L.
Coffee-tree, Kentucky—*Gymnocladus dioica* (L.) K. Koch
Colicroot—*Aletris farinosa* L.
Compass plant—*Silphium laciniatum* L.
Coneflower, purple—*Echinacea pallida* Nutt.
Coralroot, Wister's—*Corallorhiza wisteriana* Conrad
Cordgrass, prairie—*Spartina pectinata* Link
Cottonwood—*Populus deltoides* Marsh.
Cottonwood, swamp—*Populus heterophylla* L.
Crabapple, Iowa—*Malus ioensis* (Wood) Britt.
Cypress, bald—*Taxodium distichum* (L.) Rich.
Dogwood—*Cornus* spp.
Dogwood, alternate-leaved—*Cornus alternifolia* L. f.
Dogwood, flowering—*Cornus florida* L.
Dogwood, rough-leaved—*Cornus drummondi* C. A. Mey.
Dropseed, prairie—*Sporobolus heterolepis* Gray
Duckweed—*Lemna* spp.
Wolffia spp.
Wolffiella floridana (Smith) Thompson
Elderberry—*Sambucus canadensis* L.
Elm, American—*Ulmus americana* L.
Elm, rock—*Ulmus thomasi* Sarg.
Elm, slippery—*Ulmus rubra* Muhl.
Elm, water—*Planera aquatica* (Walt.) Gmel.
Farkleberry—*Vaccinium arboreum* Marsh.
Featherfoil, American—*Hottonia inflata* L.
Fern, broad beech—*Dryopteris hexagonoptera* (Michx.) C. Chr.
Fern, Christmas—*Polystichum acrostichoides* (Michx.) Schott
Fern, cinnamon—*Osmunda cinnamomea* L.
Fern, common wood—*Dryopteris intermedia* (Muhl.) Gray
Fern, filmy—*Trichomanes boschianum* Sturm
Fern, fragile—*Cystopteris fragilis* (L.) Bernh.
Fern, glade—*Athyrium pycnocarpon* (Spreng.) Tidestr.
Fern, grape—*Botrychium virginianum* (L.) Sw.
Fern, lady—*Athyrium angustum* (Willd.) Presl.
Fern, maidenhair—*Adiantum pedatum* L.
Fern, marsh—*Dryopteris thelypteris* (L.) Gray
Fern, mosquito—*Azolla mexicana* Presl.
Fern, sensitive—*Onoclea sensibilis* L.
Fern, walking—*Camptosorus rhizophyllus* (L.) Link
Feverfew, American—*Parthenium integrifolium* L.
Frogbit—*Limnobium spongia* (Bosc) Steud.
Gama grass—*Tripsacum dactyloides* L.
Gentian—*Gentiana* spp.
Gentian, closed—*Gentiana andrewsii* Griseb.
Gentian, downy—*Gentiana puberula* Michx.
Gentian, fringed—*Gentiana crinita* Froel.
Goat's rue—*Tephrosia virginiana* (L.) Pers.
Goldenrod—*Solidago* spp.
Goldenrod, Drummond's—*Solidago drummondii* T. & G.
Goldenrod, Riddell's—*Solidago riddellii* Frank
Gooseberry, pasture—*Ribes cynosbati* L.
Grama, side-oats—*Bouteloua curtipendula* (Michx.) Torr.
Grape—*Vitis* spp.
Grape, catbird—*Vitis palmata* Vahl
Grape, raccoon—*Ampelopsis cordata* Michx.
Grass of Parnassus—*Parnassia glauca* Raf.
Greenbrier—*Smilax bona-nox* L.
S. rotundifolia L.
Green dragon—*Arisaema dracontium* (L.) Schott
Gum, black—*Nyssa sylvatica* Marsh.
Gum, sweet—*Liquidambar styraciflua* L.
Hackberry—*Celtis occidentalis* L.
Hackberry, Mississippi—*Celtis laevigata* Willd.
Hazel—*Corylus americana* Walt.
Hepatica—*Hepatica acutiloba* DC.
Hercules' club—*Aralia spinosa* L.
Hickory—*Carya* spp.
Hickory, big shellbark—*Carya laciniosa* (Michx. f.) Loud.
Hickory, bitternut—*Carya cordiformis* (Wang.) K. Koch
Hickory, shagbark—*Carya ovata* (Mill.) K. Koch
Honeysuckle, Japanese—*Lonicera japonica* Thunb.
Horehound, water—*Lycopus americanus* Muhl.
Hornbeam, hop—*Ostrya virginiana* (Mill.) K. Koch
Hornwort—*Ceratophyllum demersum* L.
Hyacinth, wild—*Camassia scilloides* (Raf.) Cory
Hydrangea, wild—*Hydrangea arborescens* L.
Hymenopappus, white-bract—*Hymenopappus scabiosaeus* L'Her.
Indian grass—*Sorghastrum nutans* (L.) Nash
Indian pipe—*Monotropa uniflora* L.
Indigo, wild—*Baptisia leucophaea* Nutt.
Ivy, poison—*Rhus radicans* L.
Jack-in-the-pulpit—*Arisaema triphyllum* (L.) Schott
Juniper, creeping—*Juniperus horizontalis* Moench
Ladies'-tresses, hill prairie—*Spiranthes magnicamporum* C. J. Sheviak
Ladies'-tresses, nodding—*Spiranthes cernua* (L.) Rich.
Ladyslipper, pink—*Cypripedium reginae* Walt.
Larch, European—*Larix decidua* Mill.
Larkspur, dwarf—*Delphinium tricorne* Michx.
Leadplant—*Amorpha canescens* Pursh

Leather-leaf—*Chamaedaphne calyculata* (L.) Moench
Lily-of-the-valley, false—*Maianthemum canadense* Desf.
Lily, spider—*Hymenocallis occidentalis* (Le Conte) Kunth
Lizard's-tail—*Saururus cernuus* L.
Locust, black—*Robinia pseudoacacia* L.
Locust, honey—*Gleditsia triacanthos* L.
Locust, swamp honey—*Gleditsia aquatica* Marsh.
Loosestrife, four-flowered—*Lysimachia quadriflora* Sims
Loosestrife, swamp—*Decodon verticillatus* (L.) Ell.
Lotus, American—*Nelumbo lutea* (Willd.) Pers.
Love-grass, sand—*Eragrostis trichodes* (Nutt.) Wood
Lousewort—*Pedicularis canadensis* L.
Mallow, rose—*Callirhoe triangulata* (Leavenw.) Gray
Maple, Drummond's—*Acer rubrum* var. *drummondii* (H. & A.) Sarg.
Maple, hard—*Acer saccharum* Marsh.
Maple, red—*Acer rubrum* L.
Maple, soft—*Acer saccharinum* L.
Marigold, marsh—*Caltha palustris* L.
Mayapple—*Podophyllum peltatum* L.
Mockernut—*Carya tomentosa* Nutt.
Moss, hairy-cap—*Polytrichum* spp.
Mulberry—*Morus rubra* L.
Needlegrass—*Stipa spartea* Trin.
Nettle, false—*Boehmeria cylindrica* (L.) Sw.
New Jersey tea—*Ceanothus americanus* L.
Oak—*Quercus* spp.
Oak, black—*Quercus velutina* Lam.
Oak, black-jack—*Quercus marilandica* Muenchh.
Oak, bur—*Quercus macrocarpa* Michx.
Oak, chinquapin—*Quercus muhlenbergii* Engelm.
Oak, Hill's—*Quercus ellipsoidalis* E. J. Hill
Oak, northern red—*Quercus rubra* L.
Oak, overcup—*Quercus lyrata* Walt.
Oak, pin—*Quercus palustris* Muenchh.
Oak, post—*Quercus stellata* Wang.
Oak, shingle—*Quercus imbricaria* Michx.
Oak, Shumard's—*Quercus shumardii* Buckl.
Oak, southern red—*Quercus falcata* var. *pagodaefolia* Ell.
Oak, swamp chestnut—*Quercus michauxii* Nutt.
Oak, swamp white—*Quercus bicolor* Willd.
Oak, white—*Quercus alba* L.
Oak, willow—*Quercus phellos* L.
Orchid, grass-pink—*Calapogon pulchellus* (Salisb.) R. Br.
Osier, red—*Cornus stolonifera* Michx.
Paint brush, Indian—*Castilleja coccinea* (L.) Spreng.
Panic grass—*Panicum pseudopubescens* Nash
Panic grass, Scribner's—*Panicum oligosanthes* var. *scribnerianum* (Nash) Fern.
Papaw—*Asimina triloba* (L.) Dunal.
Partridge berry—*Mitchella repens* L.
Passion flower—*Passiflora lutea* L.
Pear, prickly—*Opuntia rafinesquii* Engelm.
Pecan—*Carya illinoensis* (Wang.) K. Koch
Pencil-flower—*Stylosanthes biflora* (L.) B.S.P.
Persimmon—*Diospyros virginiana* L.
Pickerel weed—*Pontederia cordata* L.
Pigweed, winged—*Cycloloma atriplicifolium* (Spreng.) Coult.
Pine, Austrian—*Pinus nigra* Arnold
Pine, pitch—*Pinus rigida* Mill.
Pine, Scotch—*Pinus sylvestris* L.
Pine, southern yellow—*Pinus echinata* Mill.
Pine, white—*Pinus strobus* L.
Pitcher plant—*Sarracenia purpurea* L.
Plantain, rattlesnake—*Goodyera pubescens* (Willd.) R. Br.
Plume grass—*Erianthus alopecurioides* (L.) Ell.
Polygala—*Polygala verticillata* L.
    P. polygama Walt.
Polypody—*Polypodium polypodioides* (L.) Watt
Polypody, common—*Polypodium vulgare* var. *virginianum* (L.) Eaton
Pond lily, yellow—*Nuphar advena* Ait.
Pondweed—*Potamogeton* spp.
Possumhaw—*Ilex decidua* Walt.
Poverty grass—*Danthonia spicata* (L.) Beauv.
Prairie dock—*Silphium terebinthinaceum* Jacq.
Primrose, bird's-eye—*Primula mistassinica* Michx.
Primrose-willow—*Jussiaea decurrens* (Walt.) DC.
    J. repens L.
    J. leptocarpa Nutt.
Privet, swamp—*Forestiera acuminata* (Michx.) Poir.
Puccoon—*Lithospermum canescens* (Michx.) Lehm.
Puttyroot—*Aplectrum hyemale* (Muhl.) Torr.
Rattlesnake master—*Eryngium yuccifolium* Michx.
Redbud—*Cercis canadensis* L.
Red cedar—*Juniperus virginiana* L.
Reed, common—*Phragmites communis* Trin.
Reed grass, canary—*Phalaris arundinacea* L.
Roses—*Rosa* spp.
Rose, swamp—*Rosa palustris* Marsh.
Rosin weed—*Silphium integrifolium* Michx.
Rush, twig—*Cladium mariscoides* (Muhl.) Torr.
St. John's-wort, marsh—*Triadenum walteri* (Gmel.) Gl.
Sassafras—*Sassafras albidum* (Nutt.) Nees.
Saxifrage—*Saxifraga pensylvanica* L.
Scurfpea, many-flowered—*Psoralea tenuiflora* Pursh
Sea-rocket—*Cakile edentula* (Bigel.) Hook.
Sedge—*Carex* spp.
Sedge, cotton—*Eriophorum virginicum* L.
Seed-box—*Ludwigia alternifolia* L.
Selaginella, rock—*Selaginella rupestris* (L.) Spring
Shadbush—*Amelanchier arborea* (Michx. f.) Fern.
Skullcap—*Scutellaria lateriflora* L.
Smartweed—*Polygonum hydropiperoides* Michx.
Snakeroot, white—*Eupatorium rugosum* Houtt.
Snow-bell—*Styrax americana* Lam.
Sphagnum—*Sphagnum* spp.
Spicebush—*Lindera benzoin* (L.) Blume
Spike rush, beaked—*Eleocharis rostellata* Torrey
Spring beauty—*Claytonia virginica* L.
Spurge, flowering—*Euphorbia corollata* L.
Star-grass—*Hypoxis hirsuta* (L.) Cov.
Stickleaf—*Mentzelia oligosperma* Nutt.
Stonecrop, ditch—*Penthorum sedoides* L.
Sumac, fragrant—*Rhus aromatica* Ait.
Sumac, poison—*Rhus vernix* L.
Sumac, smooth—*Rhus glabra* L.
Sumac, winged—*Rhus copallina* L.
Sunflowers—*Helianthus* spp.
Switchgrass—*Panicum virgatum* L.
Sycamore—*Platanus occidentalis* L.
Talinum—*Talinum parviflorum* Nutt.
Tamarack—*Larix laricina* (DuRoi) K. Koch
Thistle, Canada—*Cirsium arvense* (L.) Scop.
Thistle, Russian—*Salsola kali* var. *tenuifolia* G. F. W. Meyer
Thistle, swamp—*Cirsium muticum* Michx.
Three-awn grass—*Aristida desmantha* Trin. & Rupr.
    A. oligantha Michx.
    A. tuberculosa Nutt.
Toothwort—*Dentaria laciniata* Muhl.
Trillium, purple—*Trillium recurvatum* Beck
Trumpet creeper—*Campsis radicans* (L.) Seem.
Touch-me-not—*Impatiens biflora* Walt.
Tulip tree—*Liriodendron tulipifera* L.
Tupelo—*Nyssa aquatica* L.
Twayblade—*Liparis lilifolia* (L.) Rich.
Viburnum—*Viburnum* spp.
Violet—*Viola* spp.
Virginia creeper—*Parthenocissus quinquefolia* (L.) Planch.
Walnut, black—*Juglans nigra* L.
Water lily, white—*Nymphaea tuberosa* Paine.
Water-milfoil—*Myriophyllum verticillatum* L.

Waterweed—*Anacharis* spp.
Water-willow—*Dianthera americana* L.
Whitlow's grass—*Draba* spp.
Willow—*Salix* spp.
Willow, black—*Salix nigra* Marsh.
Willow, peach-leaved—*Salix amygdaloides* Anders.
Willow, Virginia—*Itea virginica* L.
Winterberry—*Ilex verticillata* (L.) Gray
Witch hazel—*Hamamelis virginiana* L.
Yew, Canada—*Taxus canadensis* Marsh.

SCIENTIFIC EQUIVALENTS OF COMMON NAMES OF VERTEBRATE ANIMALS

Fishes

Banded killifish—*Fundulus diaphanus* Jordan & Copeland
Banded pygmy sunfish—*Elassoma zonatum* Jordan
Banded sculpin—*Cottus carolinae* (Gill)
Bantam sunfish—*Lepomis symmetricus* Forbes
Bigeye chub—*Hybopsis amblops* (Rafinesque)
Blackchin shiner—*Notropis heterodon* (Cope)
Blacknose dace—*Rhinichthys atratulus* (Hermann)
Blacknose shiner—*Notropis heterolepis* Eigenmann & Eigenmann
Black redhorse—*Moxostoma duquesnei* (Lesueur)
Bluebreast darter—*Etheostoma camurum* (Cope)
Brook stickleback—*Culaea inconstans* (Kirtland)
Brown bullhead—*Ictalurus nebulosus* (Lesueur)
Central mudminnow—*Umbra limi* (Kirtland)
Channel catfish—*Ictalurus punctatus* (Rafinesque)
Cypress darter—*Etheostoma proeliare* (Hay)
Dusky darter—*Percina sciera* (Swain)
Eastern sand darter—*Ammocrypta pellucida* (Putnam)
Flathead catfish—*Pylodictis olivaris* (Rafinesque)
Goldeye—*Hiodon alosoides* (Rafinesque)
Greenside darter—*Etheostoma blennioides* Rafinesque
Harlequin darter—*Etheostoma histrio* Jordan & Gilbert
Iowa darter—*Etheostoma exile* (Girard)
Ironcolor shiner—*Notropis chalybeus* (Cope)
Lake chub—*Couesius plumbeus* (Agassiz)
Lake chubsucker—*Erimyzon sucetta* (Lacépède)
Least brook lamprey—*Lampetra aepyptera* (Abbott)
Least darter—*Etheostoma microperca* Jordan & Gilbert
Longear sunfish—*Lepomis megalotis* (Rafinesque)
Longnose dace—*Rhinichthys cataractae* (Valenciennes)
Mimic shiner—*Notropis volucellus* (Cope)
Mottled sculpin—*Cottus bairdi* Girard
Mountain madtom—*Noturus eleutherus* Jordan
Ninespine stickleback—*Pungitius pungitius* (Linnaeus)
Northern hog sucker—*Hypentelium nigricans* (Lesueur)
Northern longear sunfish—*Lepomis megalotis peltastes* Cope
Northern madtom—*Noturus stigmosus* Taylor
Ozark minnow—*Dionda nubila* (Forbes)
Pugnose minnow—*Notropis emiliae* (Hay)
Pugnose shiner—*Notropis anogenus* Forbes
Rainbow darter—*Etheostoma caeruleum* Storer
River redhorse—*Moxostoma carinatum* (Cope)
Rock bass—*Ambloplites rupestris* (Rafinesque)
Silver redhorse—*Moxostoma anisurum* (Rafinesque)
Slimy sculpin—*Cottus cognatus* Richardson
Smallmouth bass—*Micropterus dolomieui* Lacépède
Smelt—*Osmerus mordax* (Mitchell)
Southern redbelly dace—*Phoxinus erythrogaster* (Rafinesque)
Speckled chub—*Hybopsis aestivalis* (Girard)
Spottail darter—*Etheostoma squamiceps* Jordan
Spottail shiner—*Notropis hudsonius* (Clinton)
Spotted bass—*Micropterus punctulatus* (Rafinesque)
Spotted gar—*Lepisosteus oculatus* (Winchell)
Spotted sunfish—*Lepomis punctatus* (Valenciennes)
Spring cavefish—*Chologaster agassizi* Putnum
Starhead topminnow—*Fundulus dispar* (Agassiz)
Stripetail darter—*Etheostoma kennicotti* (Putnam)
Suckermouth minnow—*Phenacobius mirabilis* (Girard)
Weed shiner—*Notropis texanus* (Girard)
White crappie—*Pomoxis annularis* Rafinesque

Amphibians

Bird-voiced treefrog—*Hyla avivoca* Viasca
Bullfrog—*Rana catesbeiana* Shaw
Cave salamander—*Eurycea lucifuga* Rafinesque
Crawfish frog—*Rana areolata* Baird & Girard
Eastern narrow-mouthed toad—*Gastrophryne carolinensis* (Holbrook)
Green treefrog—*Hyla cinerea* (Schneider)
Illinois chorus frog—*Pseudacris streckeri illinoensis* Smith
Long-tailed salamander—*Eurycea longicauda* (Green)
Marbled salamander—*Ambystoma opacum* (Gravenhorst)
Mole salamander—*Ambystoma talpoideum* (Holbrook)
Red-backed salamander—*Plethodon cinereus* (Green)
Two-lined salamander—*Eurycea bislineata* (Green)
Wood frog—*Rana sylvatica* Le Conte

Reptiles

Broad-banded water snake—*Natrix fasciata confluens* Blanchard
Bullsnake—*Pituophis melanoleucus sayi* (Schlegel)
Coachwhip—*Masticophis flagellum* (Shaw)
Copperhead—*Agkistrodon contortrix* (Linnaeus)
Cottonmouth—*Agkistrodon piscivorus* (Lacépède)
Eastern box turtle—*Terrapene carolina* (Linnaeus)
Flat-headed snake—*Tantilla gracilis* Baird & Girard
Great plains rat snake—*Elaphe guttata emoryi* (Baird & Girard)
Green water snake—*Natrix cyclopion* (Dumeril, Bibron, & Dumeril)
Illinois mud turtle—*Kinosternon flavescens spooneri* Smith
Mud snake—*Farancia abacura* (Holbrook)
Northern ringneck snake—*Diadophis punctatus edwardsi* (Merrem)
Ornate box turtle—*Terrapene ornata* (Agassiz)
Queen snake—*Natrix septemvittata* (Say)
Ringneck snake—*Diadophis punctatus* (Linnaeus)
Scarlet snake—*Cemophora coccinea* (Blumenbach)
Six-lined racerunner—*Cnemidophorus sexlineatus* (Linnaeus)
Slender glass lizard—*Ophisaurus attenuatus attenuatus* Cope
Timber rattlesnake—*Crotalus horridus* Linnaeus
Western hognose snake—*Heterodon nasicus* (Baird & Girard)

Birds

American bittern—*Botaurus lentiginosus* (Rackett)
Bald eagle—*Haliaeetus leucocephalus* (Linnaeus)
Black tern—*Chlidonias niger* (Linnaeus)
Chuck-will's-widow—*Caprimulgus carolinensis* Gmelin
Cliff swallow—*Petrochelidon pyrrhonota* (Vieillot)
Common egret—*Casmerodius albus* (Linnaeus)
Henslow's sparrow—*Passerherbulus henslowii* (Audubon)
Hooded warbler—*Wilsonia citrina* (Boddaert)
Knot—*Calidris canutus* (Linnaeus)
Lark sparrow—*Chondestes grammacus* (Say)
Long billed marsh wren—*Telmatodytes palustris* (Wilson)
Mallard—*Anas platyrhynchos* Linnaeus
Marsh hawk—*Circus cyaneus* (Linnaeus)
Mississippi kite—*Ictinia mississippiensis* (Wilson)
Mockingbird—*Mimus polyglottos* (Linnaeus)
Pileated woodpecker—*Dryocopus pileatus* (Linnaeus)
Piping plover—*Charadrius meladus* Ord
Ruddy turnstone—*Arenaria interpres* (Linnaeus)
Swainson's warbler—*Limnothlypis swainsonii* (Audubon)
Turkey vulture—*Cathartes aura* (Linnaeus)
Upland sandpiper—*Bartramia longicauda* (Bechstein)
Veery—*Catharus fuscescens* (Stephens)
Western kingbird—*Tyrannus verticalis* Say
Yellow-throated warbler—*Dendroica dominica* (Linnaeus)

Mammals

Big-eared bat—*Plecotus rafinesquii* Lesson
Bobcat—*Lynx rufus* (Schreber)
Evening bat—*Nycticeius humeralis* (Rafinesque)
Gray bat—*Myotis grisescens* Howell
Illinois wood rat—*Neotoma floridana illinoensis* Howell
Indiana bat—*Myotis sodalis* Miller & Allen
Pigmy shrew—*Microsorex hoyi* (Baird)
Rice rat—*Oryzomys palustris* (Harlan)
Southeastern bat—*Myotis austroriparius* (Rhoads)
Southeastern shrew—*Sorex longirostris* Bachman
White-tailed deer—*Odocoileus virginianus* (Zimmermann)

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LLINOIS BIRDS:

'icidae

EAN W. GRABER, RICHARD R. GRABER, ETHELYN L. KIRK

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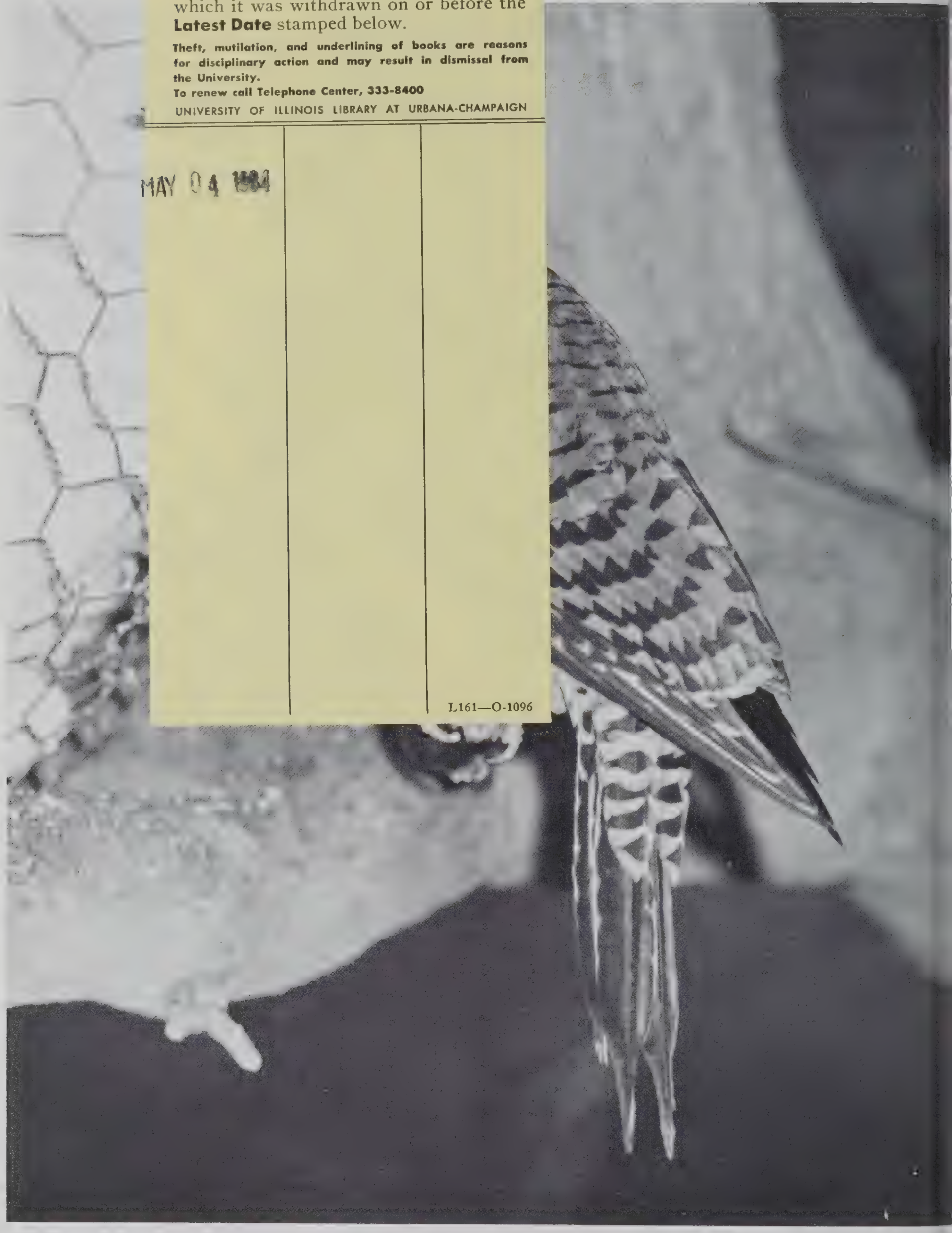

Fig. 1.—Yellow-shafted flicker at a suet feeder in Urbana, Illinois. Black moustache marks indicate the bird is a male.

LLINOIS BIRDS: Picidae

Jean W. Graber, Richard R. Graber, and Ethelyn L. Kirk

THIS IS THE SIXTH in a series of papers designed to summarize the extensive literature on Illinois birds, with special emphasis on population biology. The papers also include a large amount of previously unpublished data from the authors' continuing field work, started in September 1956, plus data contributed from numerous other observers over the years, including field notes—some dating back into he last century—from Benjamin T. Gault, Alfred O. Gross, John J. Schafer, and Frank Smith and his tudents.

The introductions to the other papers in the series, beginning with the Mimidae (Graber et al. 1970), contain statements of our procedures and policies to which the reader of this paper should refer.

The present paper deals with the woodpeckers, of which seven species occur regularly in Illinois in substantial numbers, one (the three-toed) occurs only rregularly, one (Lewis') is of accidental occurrence, and one (the ivory-bill) is extirpated and possibly extinct. References to a "white-headed woodpecker" (Musselman 1916 and 1916–1917) we assume refer *not* to the western species of that name (*Dendrocopos albolarvatus*), but to an aberrantly plumaged bird of some other species.

As we have examined the available information on the woodpeckers and other species in recent years and have observed, concommitantly, the accelerating deterioration of natural habitats in Illinois, the need for more precise knowledge of population-habitat relationships has become increasingly apparent. The ample acreages of diverse habitats that supported about 400 species of Illinois birds into the twentieth century are now being obliterated at an alarming rate. The survival of even remnant populations of many of these species will depend upon first understanding both the qualitative and quantitative characteristics of the habitat for each species and then preserving suitable habitat areas of sufficient size wherever possible.

To help with the understanding of habitat-bird population relationships, in June 1973 we inaugurated annual studies of breeding and winter populations of birds on several selected forest areas in southern Illinois where we also studied the plant populations. These studies of eight mature bottomland forests and five upland forests have revealed some interesting correlations between woodpecker population densities and vegetational composition and structure, which are discussed under each species account. To insure adequate census samples, we chose to study extensive forest tracts—each 300 acres or more in extent. No sizeable natural community is strictly homogeneous, and each of our study areas includes a number of vegetational associations—old stands of several species of trees intermingled in places with younger thickets where old trees have fallen, opening the canopy to sunlight for new growth. Considering the inherent variability of each community and other variables, such as weather, annual change, and observer alertness that affect the populations and/or the census, it is perhaps remarkable that statistically significant correlations between bird populations and vegetation characteristics were detected. Although all study areas had certain characteristics in common, each was also unique, providing us with a spectrum of forest types with which to compare bird populations.

We arbitrarily divided bottomland from upland forest on the basis of topography, including flatland forest of the floodplain and the first level above as bottomland and all else as upland. Certain consistent vegetational changes also marked the two types. The vegetation studies, made primarily in late summer and fall, 1974–1975, were censuses of plants in two types of circular quadrats—(1) 1/20th-acre quadrats in which all woody stems were identified and counted and their diameters (DBH) were measured and in which herbaceous ground cover was estimated as to percentage of ground covered and (2) 1/10th-acre quadrats in which only stems 4 inches or larger were counted and measured. The two types of plant quadrats were censused alternately at regular intervals of 550 feet within our census transect for birds, making the coverage about one vegetation quadrat per acre of forest censused for birds.

These parameters were examined for correlations between numbers of woodpeckers of each species and the woody vegetation: (1) Importance (Y) of each genus and species of woody plant. Importance is calculated from relative frequency, relative density, and relative basal area (Lindsey et al. 1958), and each of these factors was also examined separately for correlations with the bird populations. (2) Size of woody vegetation. Trees, living and dead, were classified as small (4–10 inches DBH), medium (10–22 inches DBH), or large (over 22 inches DBH). DBH (diameter breast high) was measured in inches at approximately 4.5 feet above the ground level. Woody plants of the understory were divided into three size classes (less than 1 inch, 1–2 inches, and 2–4 inches DBH).

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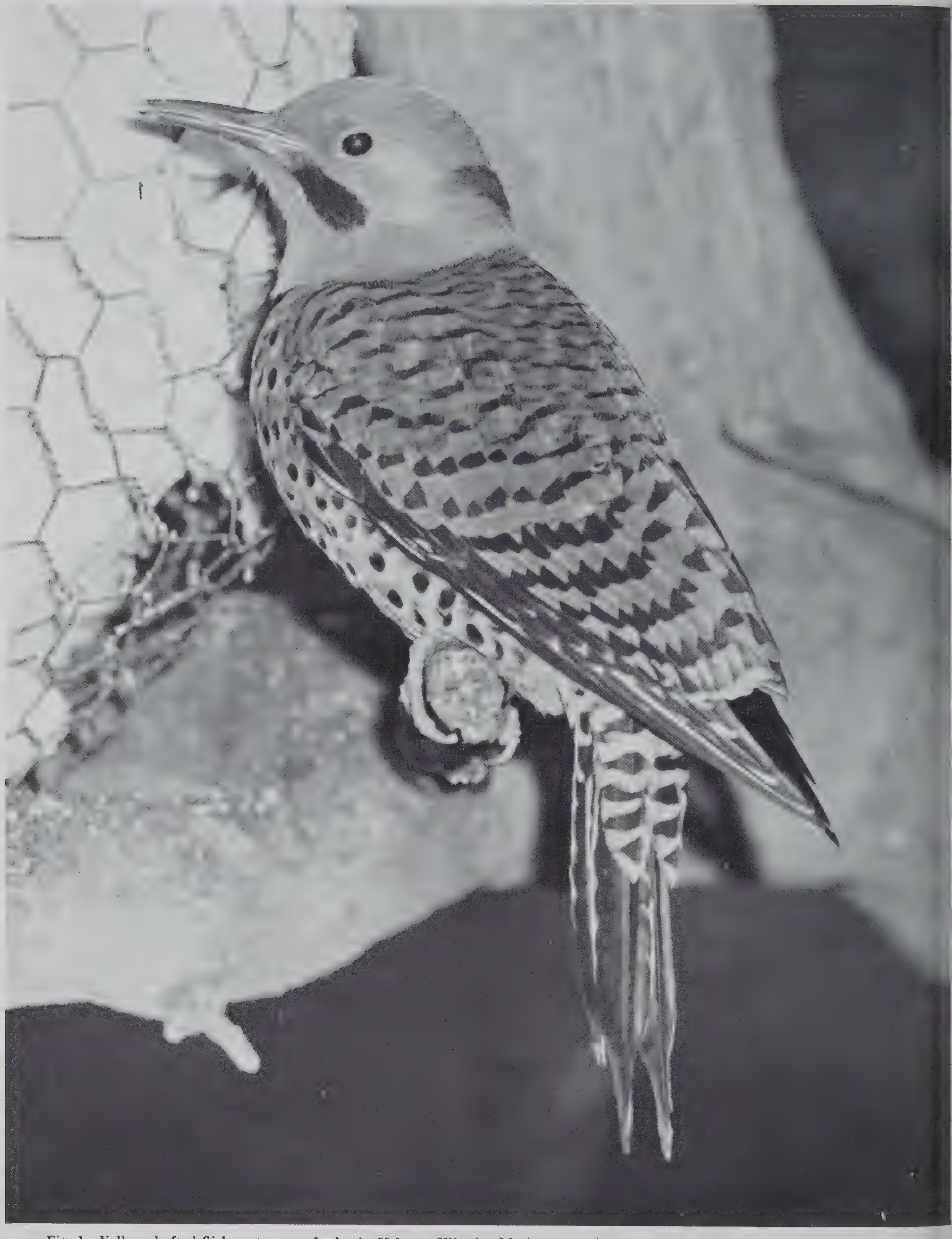

Fig. 1.—Yellow-shafted flicker at a suet feeder in Urbana, Illinois. Black moustache marks indicate the bird is a male.

ILLINOIS BIRDS: Picidae

Jean W. Graber, Richard R. Graber, and Ethelyn L. Kirk

THIS IS THE SIXTH in a series of papers designed to summarize the extensive literature on Illinois birds, with special emphasis on population biology. The papers also include a large amount of previously unpublished data from the authors' continuing field work, started in September 1956, plus data contributed from numerous other observers over the years, including field notes—some dating back into the last century—from Benjamin T. Gault, Alfred O. Gross, John J. Schafer, and Frank Smith and his students.

The introductions to the other papers in the series, beginning with the Mimidae (Graber et al. 1970), contain statements of our procedures and policies to which the reader of this paper should refer.

The present paper deals with the woodpeckers, of which seven species occur regularly in Illinois in substantial numbers, one (the three-toed) occurs only irregularly, one (Lewis') is of accidental occurrence, and one (the ivory-bill) is extirpated and possibly extinct. References to a "white-headed woodpecker" (Musselman 1916 and 1916–1917) we assume refer *not* to the western species of that name (*Dendrocopos albolarvatus*), but to an aberrantly plumaged bird of some other species.

As we have examined the available information on the woodpeckers and other species in recent years and have observed, concommitantly, the accelerating deterioration of natural habitats in Illinois, the need for more precise knowledge of population-habitat relationships has become increasingly apparent. The ample acreages of diverse habitats that supported about 400 species of Illinois birds into the twentieth century are now being obliterated at an alarming rate. The survival of even remnant populations of many of these species will depend upon first understanding both the qualitative and quantitative characteristics of the habitat for each species and then preserving suitable habitat areas of sufficient size wherever possible.

To help with the understanding of habitat-bird population relationships, in June 1973 we inaugurated annual studies of breeding and winter populations of birds on several selected forest areas in southern Illinois where we also studied the plant populations. These studies of eight mature bottomland forests and five upland forests have revealed some interesting correlations between woodpecker population densities and vegetational composition and structure, which are discussed under each species account. To insure adequate census samples, we chose to study extensive forest tracts—each 300 acres or more in extent. No sizeable natural community is strictly homogeneous, and each of our study areas includes a number of vegetational associations—old stands of several species of trees intermingled in places with younger thickets where old trees have fallen, opening the canopy to sunlight for new growth. Considering the inherent variability of each community and other variables, such as weather, annual change, and observer alertness that affect the populations and/or the census, it is perhaps remarkable that statistically significant correlations between bird populations and vegetation characteristics were detected. Although all study areas had certain characteristics in common, each was also unique, providing us with a spectrum of forest types with which to compare bird populations.

We arbitrarily divided bottomland from upland forest on the basis of topography, including flatland forest of the floodplain and the first level above as bottomland and all else as upland. Certain consistent vegetational changes also marked the two types. The vegetation studies, made primarily in late summer and fall, 1974–1975, were censuses of plants in two types of circular quadrats—(1) 1/20th-acre quadrats in which all woody stems were identified and counted and their diameters (DBH) were measured and in which herbaceous ground cover was estimated as to percentage of ground covered and (2) 1/10th-acre quadrats in which only stems 4 inches or larger were counted and measured. The two types of plant quadrats were censused alternately at regular intervals of 550 feet within our census transect for birds, making the coverage about one vegetation quadrat per acre of forest censused for birds.

These parameters were examined for correlations between numbers of woodpeckers of each species and the woody vegetation: (1) Importance (Y) of each genus and species of woody plant. Importance is calculated from relative frequency, relative density, and relative basal area (Lindsey et al. 1958), and each of these factors was also examined separately for correlations with the bird populations. (2) Size of woody vegetation. Trees, living and dead, were classified as small (4–10 inches DBH), medium (10–22 inches DBH), or large (over 22 inches DBH). DBH (diameter breast high) was measured in inches at approximately 4.5 feet above the ground level. Woody plants of the understory were divided into three size classes (less than 1 inch, 1–2 inches, and 2–4 inches DBH).

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(3) Total basal area (BA) and the ratio of the BA of each size category of woody plants to the total BA of all woody plants. Scientific names of most plants can be found in Table 14. Names of plants not found in Table 14 are given as they occur in the text.

The bottomland forest areas we censused (with the letter designations used in Fig. 13, 22, and 36) were: A—Beall Woods (Wabash County); B—Jim's Pond, 2 miles southwest of New Memphis Station (St. Clair County); C—Horseshoe Lake Nature Preserve (Alexander County); D—Union County Wildlife Refuge; E—Campbell Lake, 2 miles south-southeast of Old Duquoin (Jackson County); F—Saline (Middlefork) River, 2 miles north-northwest of Dorris Heights (Saline County); G—Heron Pond Nature Preserve (Johnson County); and H—Snider (Snyder) Lake, 3 miles east of Elkville (Jackson County). The upland forest areas we censured were the upland parts of Beall Woods and Heron Pond Nature Preserves; Pine Hills, 3 miles N of Wolf Lake (Union County); Possom Trot Trail, 2 miles SW of Elco (Alexander County); and Kaskaskia Experimental Forest, 3 miles SSW of Karbers Ridge (Hardin County).

Though still too meager, there are relatively more population figures for the Picidae than for most groups, and certain points should be made here concerning the tables that summarize these data. For the sake of completeness we have included virtually all published measurements of Illinois woodpecker populations. However, it is obvious that census data for small tracts—especially areas under 30 acres—may be badly distorted because of the relatively large amount of edge and the reduced possibility that the less common species of a fauna may be represented (Graber & Graber 1976). The reader should, therefore, use discretion in accepting the population figures presented for small areas. Also, because in most cases some interpretation is required in abstracting population figures from publications, we recommend that the reader refer to the original sources if possible. In the population tables where we have referred to the range of densities in a long series of censuses, most notably those of S. C. Kendeigh and his students, we have cited only the papers that show the extremes of the population range. Space limitations make it impossible to list all of the papers in the series. The range of population densities given for our recent (1973–1976) strip censuses is not the range for annual variation, but the range for different forest tracts, in each of which we censused at least 40 acres.

These journals were sources of Christmas-count data: *Bird-Lore* 1901–1940, *Audubon Magazine* 1941–1946, *Audubon Field Notes* 1947–1970, *American Birds* 1971–1976, and *Audubon Bulletin* 1932–1975. Since the counts are made in late December and early January of the following year, the year given in figures and tables refers to the year represented by January.

We have included scientific names, excepting nomenclature from other papers cited, and bird names in general, for which we follow American Ornithologists' Union checklist (1957) and supplements prior to 1976.

As always, we are indebted to a number of people for help, particularly for contributions of data and opportunities to examine bird specimens and use data from several scientific collections. We would particularly like to mention Frank Bellrose and Robert Crompton of the Illinois Natural History Survey; S. Charles Kendeigh of the University of Illinois; Marilyn Campbell, Gary L. Wilford, and Robert J. Schifo of the Vermilion County Conservation District (Forest Glen); Charles T. Clark of Des Plaines; Maurice Reed and Jack Keegan of Dixon; Bowie Hannah of Dix; William S. Brenneman of the Illinois Power Company; H. David Bohlen and Tim Cashatt of the Illinois State Museum; Vernon Kleen of the Illinois Department of Conservation; William B. Ahern and Merril McHenry of Greenville College; John Wanamaker of Principia College; L. Barrie Hunt of Eastern Illinois University; Donald F. Hoffmeister of the University of Illinois Museum of Natural History; Dale Birkenholz and Carol Forsyth of Illinois State University; Melvin Traylor and Emmett Blake of Field Museum; William Beecher of the Chicago Academy of Sciences; and Harlan D. Walley and William Southern of Northern Illinois University. Wallace LaBerge of the Illinois Natural History Survey, Section of Faunistic Surveys and Insect Identification, identified insects for us. We also benefited greatly in the preparation of the manuscript, photographs, and figures from the work of Eleanore Wilson and Elizabeth McConaha of the Survey's Wildlife Research Section and Larry Farlow and Lloyd LeMere, Survey Technical Photographer and Technical Illustrator, respectively. Glen C. Sanderson provided a thorough editing of the first draft of the paper, and Robert M. Zewadski edited the manuscript for publication.

YELLOW-SHAFTED FLICKER
(Colaptes auratus)

(Fig. 1 and 2)

Yellow-shafted flicker remains the most precise name for the flickers of Illinois (excepting red- or reddish-shafted birds) despite the recent recommendation that the common name for the flicker complex be "common flicker" (Eisenmann 1973). Either name is appropriate.

Spring Migration

Flickers have been recorded in all regions of Illinois at all seasons of the year, but there are well defined spring and fall migrations throughout the

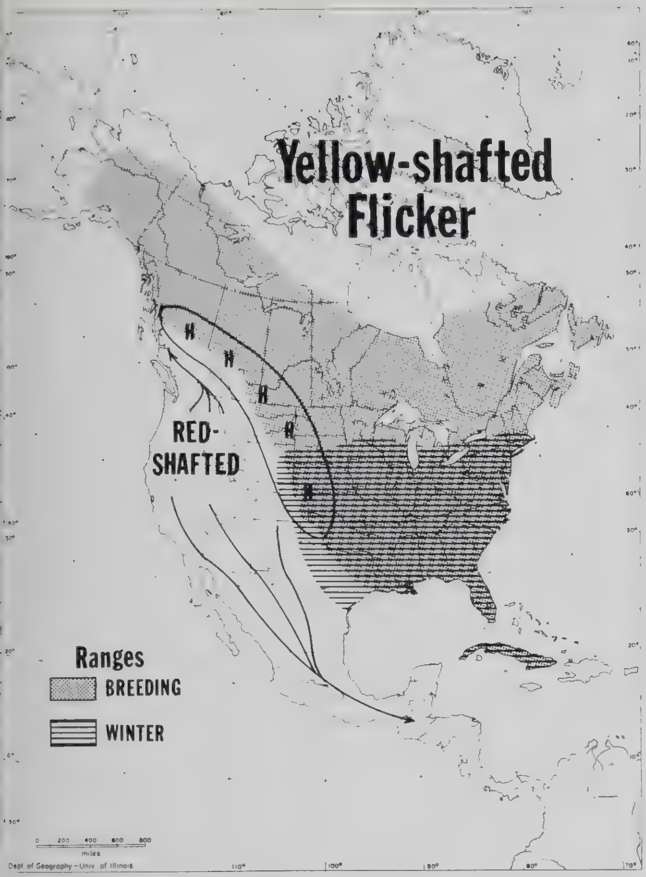


Fig. 2.—General distribution of the common flicker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat. The outlined area labelled with H's is roughly the zone of hybridization between red- and yellow-shafted birds. The lines and arrows indicate the approximate range limits for red-shafted birds.

state (Fig. 3). Flickers regularly migrate in the daytime and at night, but whether the same populations migrate both day and night is not known. The diurnal migrations are sometimes spectacular, particularly along major rivers and the Lake Michigan shore, with hundreds of birds passing a given point, singly and in flocks, in a few hours (Widmann 1907; Nolan 1958; Fawks 1967). Diurnal flights have been reported much less often in spring than in fall, suggesting that the routes differ in spring and fall. Except on the Lake Michigan shore, the number of flickers seen migrating is usually much lower in spring than in fall. However, Robert Crompton and Frank Bellrose (personal communications) have recorded diurnal migrations of flickers every spring on or near the Illinois River, where at least a few migrating birds were seen almost every day that observations were made in March and April. Topographic land features, such as large rivers, apparently concentrate the migrants, for we see the diurnal migrations away from such features but rarely and then usually at very low flight densities of only a few birds per hour. The flights, both on and off the rivers, are usually detected at relatively low altitudes—50 to 300 feet above local terrain. The flight directions are generally northward in spring, often over or paralleling a river, the headings varying in different places from northwest to directly east. On Lake Michigan the headings may be northward, paralleling the shore, or eastward around the southern tip of the lake (Nolan 1958). Diurnal flights have been seen at all hours of the day, but most commonly between 5:00 and 11:00 a.m. CST.

The night migration of flickers seems to differ in more than timing from the diurnal migration. The night flights are probably not concentrated at topographic features but move on broad fronts, as is typical of long-distance night migrants in general. We have heard flickers apparently migrating at night during April and May in central Illinois, but much more commonly in fall than in spring. We have heard them at virtually all hours of the night, from shortly after the onset of darkness (7:00 p.m. CST) to nearly dawn (4:55 a.m. CST). Strangely, the timing of calling differs in spring and in fall. In spring most of the calling comes after midnight; in fall it is more evenly distributed though with more before than after midnight. It is possible that diurnal migrations are merely extensions of the night flights, made conspicuous as birds aggregate along landscape features, but no observations support this view as yet. A large kill of flickers occurred about 10:00 p.m. on the night of 16 April 1960, when strong winds forced flickers and many other night migrants into the waters of southern Lake Michigan (Segal 1960).

In some years in southern and central Illinois, and more rarely in the north, increases occur in the flicker population in February (Lyon 1921*b*; DuMont 1947*b*), perhaps indicating the start of the spring migration. Much more commonly the onset of the migration throughout the state is noted during March (Fig. 3; Cooke 1885*a* and 1888; Musselman 1913), varying year to year from early to late March (Widmann 1907). The early part of the migration often coincides with robin migrations (Cooke & Widmann 1884). Peak numbers occur from mid-March to mid-April in southern Illinois and from late March to late April in central and northern Illinois (Fig. 3). At Chicago Beal (1886) recorded on 17 April a great wave of flickers, which had departed by the 23rd. Migrant flickers are often seen at this season foraging in pastures in flocks of a dozen or more birds.

Distribution

The complex of flickers, including both yellow-shafted and red-shafted, occurs throughout much of North America and Mexico and south to Nicaragua. In winter the range of the yellow-shafted flicker contracts mainly into the eastern and central United States (Fig. 2).

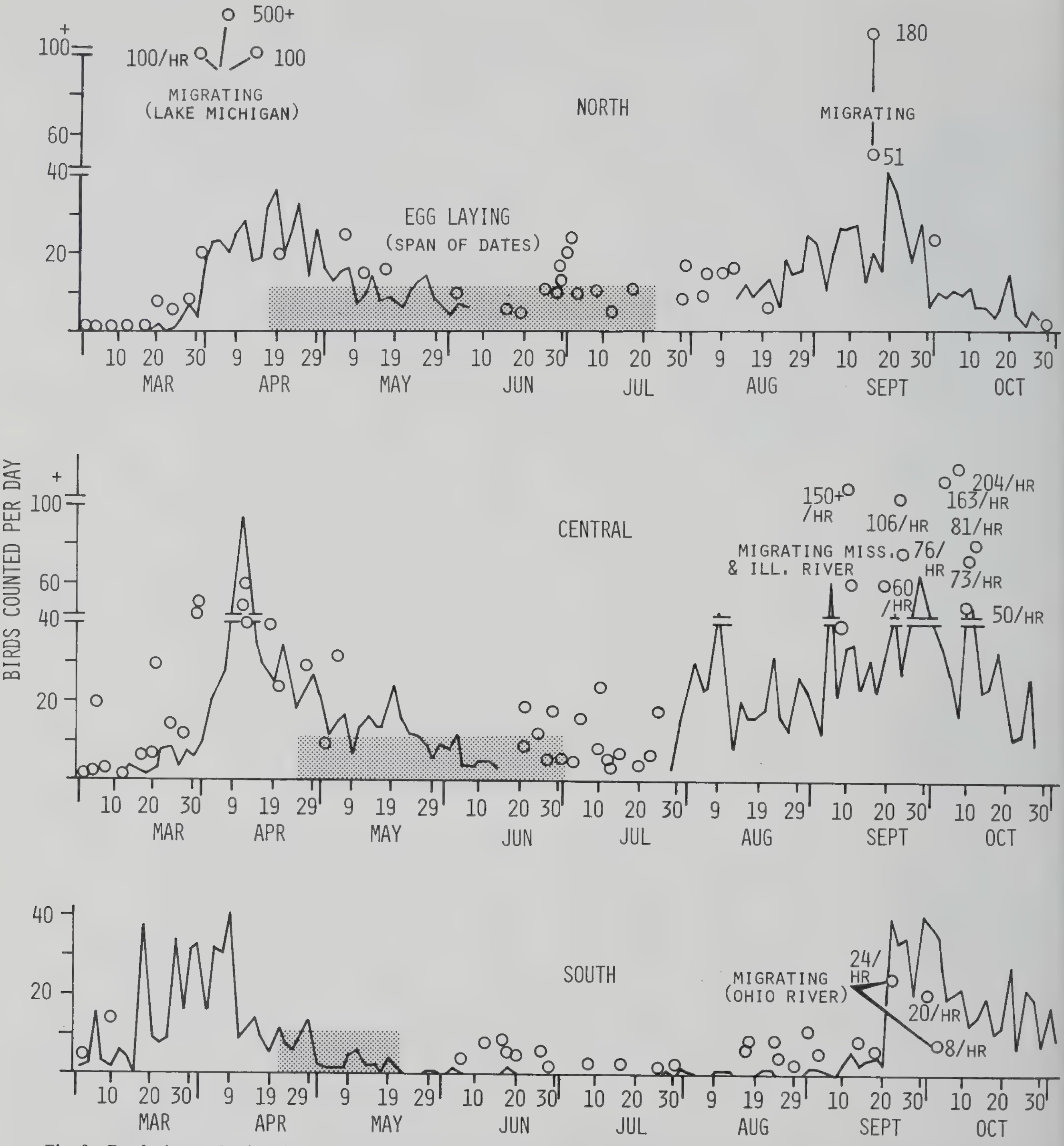


Fig. 3.—Egg-laying and migration seasons of the yellow-shafted flicker in different regions of Illinois (see Fig. 5 for regions). Spring and fall graph lines show the higher daily count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

Yellow-shafted flickers almost certainly nest in every county in the state, but their true distribution is still unknown (Fig. 4).

Nesting Habitats and Populations

The 1957–1958 state censuses showed the flicker to be the most common woodpecker in Illinois, and this ranking in population probably has not changed. As a cavity-nesting species like other woodpeckers, the flicker requires at least medium-sized trees for nest sites. However, the flicker is less a forest species than any other Illinois woodpecker though the red-head shows similar habitat preferences. Both species show affinities for more open habitats and edge situations.

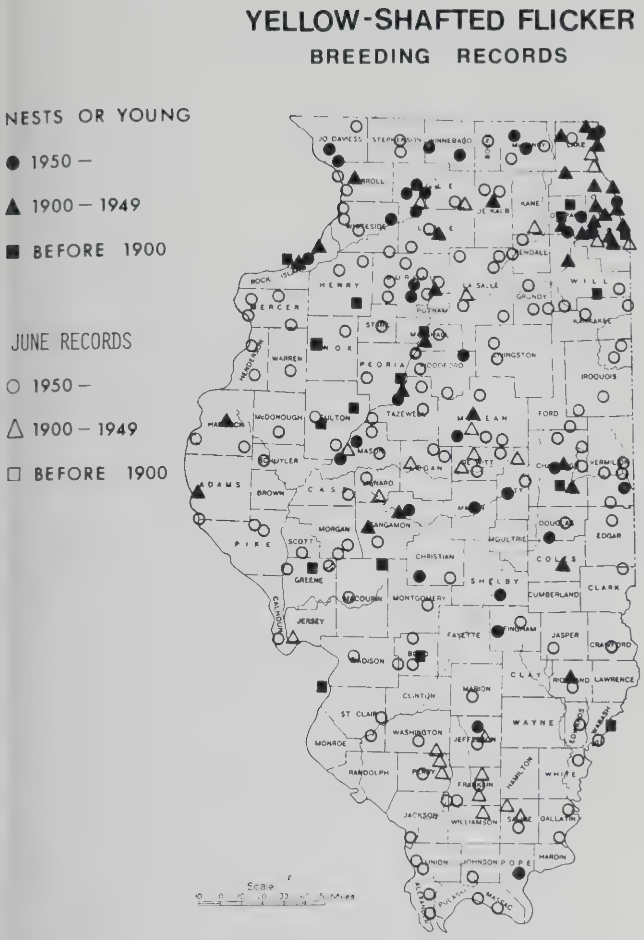


Fig. 4.—Breeding records of the yellow-shafted flicker in Illinois. Hollow symbols represent birds seen or heard in June.

In forest areas flickers tend to avoid the interior and occupy the forest edge (Hankinson 1915; Kendeigh 1941). The most striking difference in summer habitat between the flicker and the red-headed woodpecker is the flicker's greater use of urban residential habitat (Tables 1 and 10).

Grass foraging areas are important to the flicker (Swink 1959), and pastures have been a significant habitat for the species (Table 1).

The comparative censuses of 1907–1909 and 1957–1958 showed that both the flicker and red-head underwent drastic population reductions—on the order of 90 percent in about 50 years in Illinois. The change was caused by something besides the loss of habitat, because the densities of populations declined in nearly all habitats (Table 1). A loss of habitat acreage would not necessarily change population densities. As late as the 1930's observers in northern Illinois believed the flicker population was increasing (Eifrig 1930*a* and 1938; Blocher 1934). In 1933 in a four-block area of Congress Park, Illinois, Bodensten (1934) counted 22 flicker nests—a very high density not even approached in recent decades. The decline after 1930 coincides strikingly with the establishment of the starling population in the state. The starling was still rare in Illinois in 1928 (Eifrig 1930*b*), but its population grew rapidly in the 1930's, competing increasingly with the native cavity nesters. In urban residential habitat, where flickers and starlings are perhaps most competitive, flicker and starling populations are inversely correlated (Graber & Graber 1963).

The reduction in densities of flicker populations could also have resulted to some extent from a deterioration of habitat quality, e.g., the loss of nest trees from pastures, but there have been no quantitative studies to demonstrate such changes. Besides the decline in population densities, some of the overall population decline can be attributed to the loss of acreage of some favorite nesting habitats, such as hedge rows, savannahs, orchards, and pastureland.

Since the time of the first statewide censuses (1907), flicker populations have apparently always been highest in the northern region of the state, lowest in the south (Table 1). This difference is not merely a matter of habitat availability, as population densities have been consistently higher in the north regardless of habitat. Why habitats in the north support more flickers than the same habitats in the south is a question that warrants investigation. The flicker's population decline, although statewide, was particularly severe in the south for reasons not clear. Our subjective impression is that the flicker population has been increasing in recent years, particularly in the south.

Nest sites of flickers mentioned in the Illinois literature are listed in Table 2. Nests are often located in dead trees and in softwood species, such as poplars, usually in the trunks. Burns (1900) felt that flickers rarely excavated completely sound (healthy) trees. Many observers noted that nest trees were large or old (Strode 1888; Silloway 1906; Schafer 1933; Work 1933). As the nest chamber may be 6–7 inches in diameter (Ford 1939), at least one fair-sized tree is required in such open nesting habitat as pasture. The essential requirements for flicker habitat have never been determined.

Published data on 46 flicker nests, mainly in northern and central Illinois, showed the height to vary from 4 to 45 feet (average: 16 feet), with no obvious preferred height.

Data on flicker territory size are scant. One territory measured by Calef (1953*a* and 1953*b*) in McLean County was 1.55 acres, a small area by comparison with territories of the red-bellied woodpecker (Calef 1953*a*). A study of territory size in more open savannah habitat versus forest-edge would be particularly interesting.

Nesting Cycle

The homing of flickers to the same nesting territory—even to the same nest cavity between years—has

TABLE 1.—Breeding populations of yellow-shafted flickers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Suburban residential	8	50	1916	Nest	Richland (S) [b]	Cooke 1916
Urban residential	160	6	1958	Strip	North	Graber & Graber 1963
Urban residential	75	8	1958	Strip	Central	Graber & Graber 1963
Urban residential	98	4	1958	Strip	South	Graber & Graber 1963
Modified woodland (human housing)	28	29	1937	Nest	Lake (N)	Beecher 1942
Unmodified woodland	27	22	1937	Nest	Lake (N)	Beecher 1942
Oak-maple forest	55	0–7 (avg 3.2)	1927–1943	Map	Champaign (C)	Kendeigh 1944
Oak-maple forest edge	1.25 miles[c]	0–8[c] (avg 3.1)	1944–1957	Map	Champaign (C)	Kendeigh 1948*b*; Kendeig & Gillespie 1955
Oak-maple forest edge	1.25 miles[c]	8–22[c] (avg 14.0)	1958–1974	Map	Champaign (C)	Kendeigh 1960*b*; Kendeig & Brooks 1964*b*
Oak-maple forest	64	3	1943	Map	Champaign (C)	Johnston 1947
Forest (all types, including edge)	177	5–6 (avg 5.6)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	214	2–3 (avg 2.3)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	60	5–13 (avg 10.0)	1907, 1909	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	340	0	1957–1958	Strip	South	Graber & Graber 1963
Virgin floodplain forest	77	4	1948	Map	Sangamon (C)	Snyder et al. 1948
Mature bottomland forest	63	3–6 (avg 4.8)	1950–1951	Map	McLean (C)	Calef 1953*a*
Mature bottomland forest	1,077	0–7 (avg 0.7)	1973–1975	Strip	South	This paper
Grazed bottomland woods	53	7	1955	Map	Macon (C)	Chaniot & Kirby 1955*b*
Mature upland forest	479	0–2 (avg 0.4)	1974–1975	Strip	South	This paper
Upland second-growth forest	56	4–11 (avg 7.3)	1941–1944	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*, 1944*b*
Upland oak-hickory	24	13	1967	Map	Hancock (C)	Franks & Martin 1967
Second-growth hardwoods	15	27–40 (avg 33.3)	1937–1938	Map	Rock Island (N)	Fawks 1937, 1938
Woods (unspecified)	20	0–10 (avg 3.3)	1914–1916	Nest	Rock Island (N)	J. J. Schafer (unpublishe notes 1914–1923)
Woods (unspecified)	54	0–9 (avg 6.0)	1917–1923	Nest	Rock Island (N)	J. J. Schafer (unpublishe notes 1914–1923)
Orchard	45	4–21 (avg 11.1)	1907, 1909	Strip	South	Graber & Graber 1963
Orchard	78	0	1957–1958	Strip	South	Graber & Graber 1963
Late shrub	21	32	1966	Map	Vermilion (C)	Karr 1968
Shrub area	32	0–6 (avg 3.1)	1957–1958	Strip	North	Graber & Graber 1963
Shrub area	181	0	1957–1958	Strip	Central & South	Graber & Graber 1963
Swampy prairie	64–67	3–9 (avg 6.1)	1941–1944	Map	Sangamon (C)	Robertson 1941*a*, 1942*a*, 1944*a*
Pasture	193	17	1909	Strip	North	Graber & Graber 1963
Pasture	279	3	1957–1958	Strip	North	Graber & Graber 1963
Pasture	442	8–15 (avg 10.4)	1907, 1909	Strip	Central	Graber & Graber 1963
Pasture	172	0–2 (avg 1.2)	1957–1958	Strip	Central	Graber & Graber 1963
Pasture	882	3–4 (avg 3.3)	1907, 1909	Strip	South	Graber & Graber 1963
Pasture	120	0	1957–1958	Strip	South	Graber & Graber 1963

[a] All figures were converted to birds per 100 acres (territorial males or nests × 2).
[b] S refers to the southern region of Illinois, C to the central, and N to the northern region, as shown on winter distribution maps, e.g., Fig. 5.
[c] These entries are miles of forest edge and birds per mile of edge.

been demonstrated from banded birds in northern Illinois (Lyon 1921*a*; Smith 1925; Lincoln 1927).

The familiar "wick-er–wick-er" call may be heard in any month of the year in Illinois, but calling increases in February and March through May. Courtship and territorial displays, often seen through March and April (Musselman 1934–1935; Craigmile 1945), are interesting and fairly complicated in pattern (Egan 1923). Particularly in April we have seen heated territorial fights between two flickers, strug-

TABLE 2.—Nest sites of yellow-shafted flickers in Illinois.

Site		Number of Nests
Apple tree[a]		15
Dead stub (unidentified tree)		13
Oaks (bur, white, blackjack, red, & unspecified)	9	11
Oak (dead)	2	
Elm (unspecified)	1	8
Elm (dead)	7	
Poplar (unspecified)	4	7
Cottonwood (dead)	3	
Willows (black and unspecified)		6
Bird houses		6
Maples (silver and unspecified)		3
Ash (unspecified)		2
Catalpa (unspecified)		1
Pine (dead)		1
Shagbark hickory		1
Walnut		1
Hackberry		1
Locust (unspecified)		1
Building		1
Telephone pole, fencepost		2
Total		*81*

[a] Scientific names are not given, as scientific names were not provided in the original sources.

gling on the ground often in open grass areas. In April and May pairs of flickers are also often seen mating. Ridgway (1923) noted that in southern Illinois flickers were paired by 7 March. There is little in the Illinois literature about "drumming" behavior by flickers, either of a descriptive nature or on its timing or function (Craigmile 1945).

The same nest tree and even the same cavity may be used year after year by flickers (Silloway 1906; Schantz 1934–1935) and sometimes by the same bird(s) (Lyon 1921*a*). Schantz (1934–1935) observed flickers nesting in a dead cottonwood at Berwyn every year from 1931 to 1933, each year excavating a new hole. We have observed the excavation of cavities in different parts of the state, particularly in April and May. Eifrig (1930*b*) noted that cavity excavation took 3–4 days at one nest, but other observers give the time requirement as a week to 20 days or more (Burns 1900). Cavities of 11 (mainly northern) Illinois nests varied from 8 to 24 inches in depth (average 15.5 inches). One tree cavity used by flickers was 6 inches in diameter. Ford (1939) recommended dimensions of nest boxes for flickers as (in inches): floor, 7 × 7; depth, 16–18; entrance above floor, 14–16; and entrance hole, 2½ inches in diameter, the box to be placed 6–20 feet high.

No nest structure other than the cavity is made, the eggs being laid on the wood chips and dust on the floor of the cavity.

The eggs, typical of woodpeckers in general, are immaculate white. Data on 49 clutches from old (1879–1915) museum records and literature, mainly from northern and central Illinois, had this distribution: 5 eggs, 4 sets; 6 eggs, 13; 7 eggs, 9; 8 eggs, 10; 9 eggs, 8; 10 eggs, 4; 12 eggs, 1. Average clutch size for the 49 sets was 7.45 eggs. As the early oologists tended to save and publish on large sets particularly, the above distribution may be distorted. There are no recent data on clutch size for the flicker.

The flicker is renowned as an indeterminant layer, and in northern Illinois Abbott (1897) induced (by removing eggs as they were laid) a laying of 24 eggs at one nest and Bodensten (1932) a laying of 33 eggs at another. Goelitz's (1915) record of a 12-egg set was possibly a natural clutch.

The only published data on the time requirements of a nesting cycle for the flicker in Illinois are those of Holcombe (1931) and Eifrig (1931). Holcombe observed a nest in Zion that required 43 days from the laying of the first egg (of nine) to the fledging of the young. Assuming incubation began with the last egg, the incubation and nestling periods together would have been 35 days. At another nest Holcombe's data indicated an incubation period of about 12 days, leaving about 23 days as the period of nestling life.

There are no data on nesting success for any Illinois population of flickers, nor is it known whether more than one brood is attempted.

Many references have appeared in the Illinois literature on the subject of flickers and interspecific competition for nest cavities. The general tone of the comments has been that though flickers have been well able to compete with house sparrows (Bartel 1931), they have lost cavities to starlings (Holcombe 1931 and 1938; Donovan 1934; Blocher 1936*b*; Smith & DuMont 1945*a*). Despite the starling's domination, flickers may often raise broods after starlings have nested (Schafer 1933; Moseley 1947). Bodensten (1935) observed contemporaneous successful nests of starlings and flickers in the same tree only 2 feet apart. Flickers may also compete for or share cavities with squirrels and screech owls (Strode 1888; Lyon 1930; Ford 1933; Work 1933; Hammond 1934–1935), but the effects of these relationships on any population are unknown. Use of the cavities by different species is often staggered in time (Ford 1933). Reller (1972) observed instances of the use of the same nest tree (different cavities) by flickers and red-heads in one case and flickers and red-bellies in another. In both cases the nestings continued relatively harmoniously though the flickers were subordinate to both other species during occasional instances of strife.

An interesting study of animal behavior was Lyon's (1922) observations at a cavity used alternately by squirrels, screech owls, and flickers, and finally by a screech owl and flicker together. The owl apparently brooded and perhaps even attempted to feed a brood of young flickers, while the parent flickers continued to feed their young even as the owl sat. This bizarre relationship lasted at least 5 days until the flickers fledged. The two species are not always so harmonious; a study by Brown & Bellrose (1943) showed that flickers constituted 5 of 259 prey items of screech owls in southern and central Illinois.

Fall Migration

In early August flickers generally appear to be in worn, dirty plumage, but by the end of August some seem to be in largely fresh plumage. Whether this change reflects molt in the local population or an influx of other populations, we do not know.

Frank Bellrose and Robert Crompton, Illinois Natural History Survey, (personal communication) have witnessed diurnal flights of flickers along the Illinois River as early as 31 July in 1966 and regularly through August each year, but at generally low flight densities—usually under 20 birds per hour. The flights increase in number and density, particularly after the first of September, to densities of 50 or more per hour on some days (Fig. 3). These flights are similar to the diurnal flights in spring, though on a reverse heading and generally downstream—southwest to west-southwest along the Illinois River in Mason County and south along the Mississippi River in Adams County. The birds fly singly and in flocks "Indian file," each group using about the same route on a narrow corridor and flying from tree-top level to altitudes of 500 feet or more. Such diurnal flights have been seen most often in the morning. The number of flights and the flight densities decline greatly after mid-October in central Illinois (Fig. 3), but flights have been seen as late as 21 November. In northern Illinois on the Mississippi River the migration appears to fall off much earlier—at the end of September (Fig. 3)—but the observed difference may merely be annual variation. In southern Illinois we have never detected the diurnal flights on the Mississippi, and on the Ohio River the flight densities have always been low by comparison with densities on rivers in central and northern Illinois (Fig. 3). An important but unanswered question is whether flight densities are different from one side of a river to the other. Thus far, our observations on the Ohio River have been restricted to the Illinois side. Diurnal migrations of flickers have not been reported on the Rock and Wabash rivers but should be looked for on these and other major streams.

At least one large diurnal fall flight of flickers has been recorded on the Chicago lake front (Boulton & Pitelka 1938). The diurnal migrations are not restricted to waterways but have rarely been reported elsewhere. Benjamin Gault (unpublished notes 1912) counted 51 migrating flickers in 5 minutes on 19 September at Glen Ellyn, and we have seen light migrations (three birds per hour) in November in Pope County away from the Ohio River.

In the same period that diurnal migrations of flickers are most evident, there are regular nocturnal migrations of the species. We have heard flickers apparently migrating over central Illinois on many nights between late August and the first week in October. These flights were not obviously associated with waterways or other landscape features, but were audible at various stations across the state at all hours of the night.

Flickers are relatively uncommon victims in the kills at television towers in central Illinois. We have records of only eight flickers among approximately 12,000 birds of all species picked up and identified from the towers. The flickers were killed between 27 September and 7 October, a relatively small part of the fall migration period when the migrant flicker population is at its maximum (Fig. 3). These data differ somewhat from those in Graber (1968), reflecting a great increase in the amount of field data since that paper was submitted. The low kill of flickers is puzzling in view of the number of flickers seen in the fall. The data seem to imply that most of the migration is diurnal. Are different populations in-

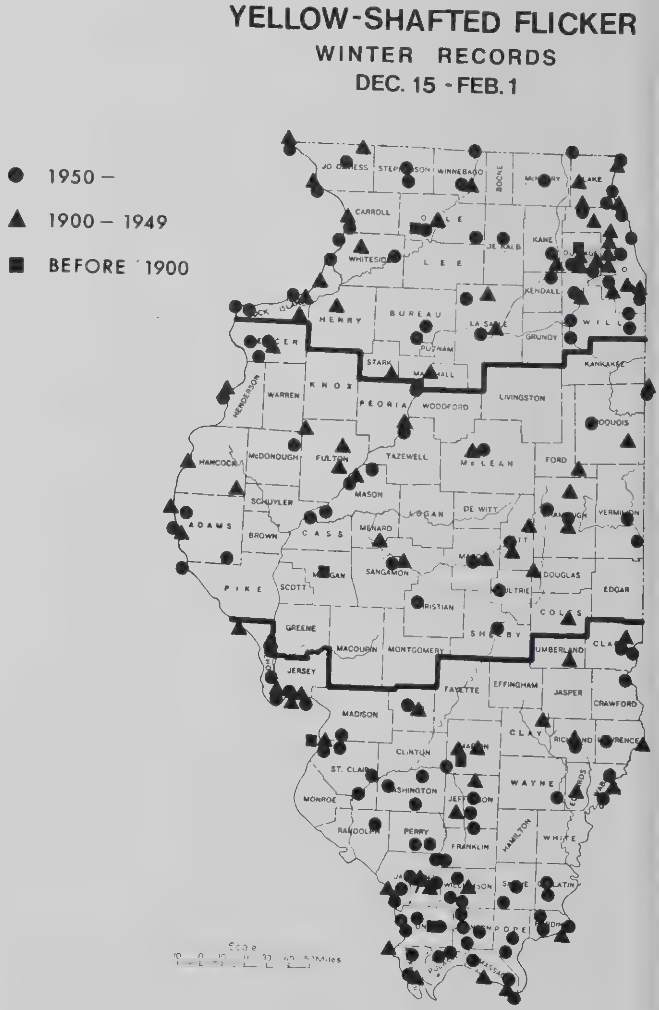


Fig. 5.—Winter records of the yellow-shafted flicker in Illinois. Heavy horizontal lines separate the three regions (north, central, and south) referred to in the text.

volved in diurnal versus nocturnal migration in this species?

Lyon's (1925) record of a flicker banded at Waukegan in June 1918 and recovered at Monroe, Louisiana, in July 1925 seems to place an Illinois breeding bird deep in the winter range at a very early date. Probably more representative of the actual migration movement for the species is a flicker banded at Zion in June 1930 and recovered at Hamilton, Alabama, 9 October 1930 (Cooke 1937). Seven published records of flickers banded mainly in summer in northern Illinois and recovered mainly in winter are remarkably consistent in location at two areas—northeastern Louisiana and northwestern Alabama (Lyon 1925; Anonymous 1931; Cooke 1937 and 1946; Lincoln 1939; Labahn 1941).

Our counts for southern Illinois (Fig. 3) show an abrupt increase in the flicker population after 20 September, probably representing large influxes of more northern populations, which stand out because of the relatively low breeding population in the south.

The ratio of our spring-to-fall counts of foraging flickers, i.e., excluding birds in actual migration flights, does not indicate high productivtiy. In northern Illinois, we saw 1.0 flicker in spring (March–May, inclusive) to 1.1 in fall (August–October, inclusive), whereas the ratio in the central region was 1.0 to 1.5 and in the south 1.0 to 2.2. East-central Illinois had higher fall populations than had west-central Illinois (1.6 to 1.0) though the spring populations were nearly the same.

Winter Populations

Yellow-shafted flickers may be found in virtually all parts of the state in winter (Fig. 5), and the number of flickers statewide may be nearly as great as the summer population. However, in winter most (70–80 percent) of the state's flicker population is concentrated in southern Illinois. Most of the rest of it is in central Illinois with relatively little of it in the northern region (Graber & Graber 1963).

This distribution is also indicated in the Christmas counts (Fig. 6); the average number of flickers per party hour (1945–1975) is nearly six times as great in the south as in the north and two times as great in the south as in the central part of the state. Occasionally large flocks of flickers may be found even in the north in winter (Blake 1948).

Early in this century, when corn was hand picked and large areas were left with stalks standing, cornfields were a favorite winter habitat for flickers (Table 3). Corn stubble left from mechanically picked corn does not support nearly such high population densities of flickers. However, it is still an important foraging habitat because there is so much of it, and it is still used even though at low densities. Forest, shrub areas, and pastures are also regularly used winter habitats. In the south we have found bottomland forest to have consistently higher populations of flickers than upland forest (Table 3). Urban habitat appears less important to the flicker in winter than in summer. The reference in Graber & Graber (1963: 474) to hayfields as winter habitat for flickers, including the population density cited (6 birds per 100 acres) is erroneous. Hayfields are not important as winter habitat, and we are totally at a loss to explain the error.

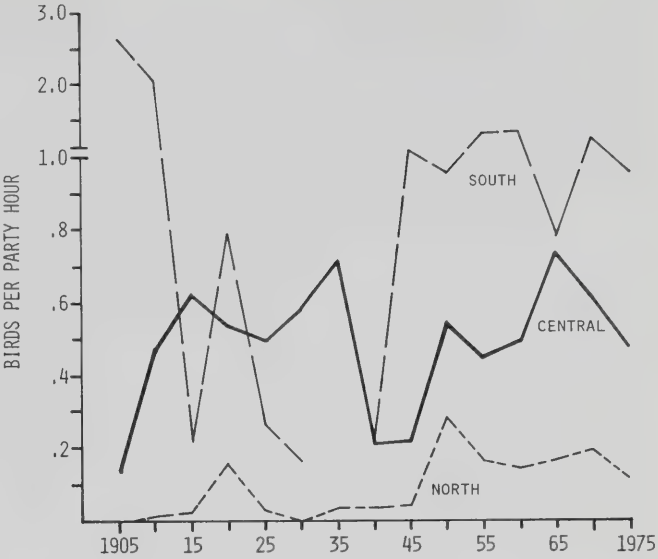


Fig. 6.—Yellow-shafted flickers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average.

Winter flicker populations in five upland and eight bottomland woods in southern Illinois were examined to see if any correlation existed between the bird and the woody vegetation in these woods (see introduction). Flicker populations were also compared with those of other woodpeckers in the same woodlands. The only correlation found ($r = 0.597$, $P = <0.1$) indicated that flicker populations are highest in bottomland woodlands that have over 20 percent of the basal area of their trees in the small tree category. Winter numbers were 5–13 times as great as those in summer in these bottomland woods and 7–8 times as great as those in summer in the upland woods.

Though at least part of the Illinois breeding population of flickers winters well south of Illinois (see under Fall Migration), the sources of the Illinois winter population are not known.

Food Habits

The flicker is well known as a consumer of ants (Forbes 1882*a*; Ekblaw 1919). Gross & Forbes (1909) stated that ants made up 45 percent of the flicker's diet. Much of the food is taken from the ground. A specimen taken in Tazewell County 24 May 1881

TABLE 3.—Winter populations of yellow-shafted flickers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Urban residential	191	0.5	1976	Strip	Central	This paper
Urban residential	191	1	1976	Strip	South	This paper
Suburban woodlot	20	0–5	1968–1972	Map	Lake (N)[a]	Miller & Miller 1968, 1970
Oak-maple forest edge	55	0–16 (avg 7.3)	1925–1943	Map	Champaign (C)	Kendeigh 1948*a*
Oak-maple forest edge	1.25 miles[b]	0–1[b] (avg 0.2)	1944–1948	Map	Champaign (C)	Kendeigh 1948*a*
Oak-maple forest edge	1.25 miles[b]	0–3[b] (avg 1.4)	1949–1975	Map	Champaign (C)	Kendeigh & Brooks 1963*a*; Kendeigh, James, & Weise 1953
Forest (all types, including edge)	110	0	1907, 1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	152	0–1 (avg 0.5)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	241	2	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	2–7 (avg 3.8)	1957–1958	Strip	South	Graber & Graber 1963
Mature upland oak-hickory forest	772	0–11 (avg 2.5)	1974–1976	Strip	South	This paper
Mature bottomland forest	1,398	0–24 (avg 5.3)	1974–1976	Strip	South	This paper
Bottomland woods	50	(+)[c]–2	1950, 1953	Map	Cook (N)	Montague 1950, 1953
Virgin bottomland forest	50	4	1947	Map	Piatt (C)	Fawver 1947*b*
Grazed bottomland woods	53	2	1955–1957	Map	Macon (C)	Chaniot & Kirby 1955*a*, 1956; Kirby & Chaniot 1957
Shrub area	87	0	1957–1958	Strip	North & Central	Graber & Graber 1963
Shrub area	101	2–5 (avg 3.0)	1957–1958	Strip	South	Graber & Graber 1963
Shrubby field and forest edge	85	(+)–1	1955–1956	Map	Richland (S)	Shaw & Stine 1955; Shaw et al. 1956
Shrubby field	40	(+)–2	1960–1965, 1968	Map	Lawrence	Shaw 1961, 1962
Pasture	440	(+)	1907	Strip	North	Graber & Graber 1963
Pasture	343	1	1907	Strip	Central	Graber & Graber 1963
Pasture	208	3	1907	Strip	South	Graber & Graber 1963
Pasture	93	1–4 (avg 2.1)	1957–1958	Strip	South	Graber & Graber 1963
Cornfields (harvested)	491	(+)	1957	Strip	Central	Graber & Graber 1963
Cornfields (stalks standing)	222	8	1907	Strip	South	Graber & Graber 1963
Cornfields (stalks removed)	117	2	1907	Strip	South	Graber & Graber 1963
Cornfields (machine picked)	277	1–2 (avg 1.4)	1957–1958	Strip	South	Graber & Graber 1963

[a] N refers to the northern region of Illinois, C to the central region, and S to the southern, as shown on winter distribution maps, e.g., Fig.5.
[b] These entries are miles of forest edge and birds per mile of edge.
[c] The plus symbol (+) indicates fewer than one bird per 100 acres.

had eaten nothing but ants. Similarly, a male from Champaign County on 3 October 1968 had packed in its stomach and esophagus 20 milliliters of ants (mainly adults with some pupae), 90 percent of which were one species of *Formica,* plus species of *Lasius* and *Acanthomyops.* (A species of *Lasius* was also used in anting by a flicker (Southern 1963)). This bird's food and its fresh undigested condition indicated that the bird had fed in several different areas in a brief span of time and in different habitats from open fields to woods (Wallace E. LaBerge, Illinois Natural History Survey, personal communication). Forbes (1881) found no indication of predation on canker worms by a flicker taken in a heavily infested orchard. In the deep south, at least, the flicker is a very important predator on corn borers (Black et al. 1970), and though this has apparently not yet been reported in Illinois, the large winter population of flickers in corn stubble in Illinois may relate to such predation. In Georgia flickers have also been observed feeding on corn ear caterpillars of an undesignated species (Dorsey 1925), and flickers are an important predator on the southwestern corn borer in Arkansas (Wall & Whitcomb 1964).

Beal's (1911) extensive study of the food of North American woodpeckers includes some data on Illinois specimens. Beal found that the yellow-shafted flicker's diet was about 61 percent animal matter and 39 percent vegetable. Ants were clearly the favorite food every month, comprising about 50 percent of the year's diet and going as high as 80 percent in May and as low as 11 percent in December. Predaceous ground beetles (Carabidae), Hemiptera (chinch bugs), and Orthoptera (grasshoppers, crickets) were regular items in the diet in small amounts.

Small, mainly wild, fruit was important in the flicker's diet from summer to October, when such fruit constituted about 42 percent of the food. Especially important were species of *Rubus* (blackberries, raspberries, etc.) and *Rhus* (poison ivy, sumac), plus wild black cherries, hackberries, grapes, and dogwood. The flicker may be an important agent in the distribution of such plants. In the fall we have often seen flickers feeding on the fruit of poison ivy. They also eat pokeberries and wild grapes (Comfort 1940), and Gault (1932) found one eating pears on a tree. Flickers are also fond of suet (Patterson 1923). There is no definite reference to the use of mast by flickers in Illinois in contrast to the abundant literature on the subject for red-headed woodpeckers.

Longevity and Mortality

Survival and longevity of flickers have not been studied systematically on a population basis in Illinois. The two oldest flickers for which band recoveries have been published were at least 7 years and 1 month (Lyon 1925) and 5 years (Remington 1944). The remains of at least a few flickers have been found in Indian kitchen middens dating back perhaps 10,000 years (Baker 1936; Parmalee 1959, 1962, and 1969). More recent problems with humans relate to possible insecticide poisoning (Scott et al. 1959) and highway mortality (Flint 1926 and 1934–1935; Komarek & Wright 1929; Blocher 1936*a;* Starrett 1938). Some flicker mortality has been ascribed to severe weather in winter and spring (Schafer 1921; Roseberry 1962).

The screech owl and red fox have been recorded as predators, or at least scavengers, on flickers in southern and central Illinois (Brown & Bellrose 1943; Knable 1970). Coffin (1970) described a strange interplay, apparently unrelated to predation, between a flicker and a sparrow hawk. Perhaps unique was the instance of a flicker made unable to fly because of heavy poplar resin accumulations on its wings and tail (Brodkorb 1928).

The only reference we've found on the pathology of flickers in Illinois is Labisky & Mann (1961) on a case of avian pox.

RED-SHAFTED FLICKER (*Colaptes auratus* subspecies)

There are a number of Illinois records of flickers with reddish color in their flight feathers (Ridgway 1914; Lyon 1934; Labahn 1941; Comfort 1949; Mumford 1959*a* and 1959*b;* Southern 1962; Petersen 1966 and 1967; Anderson 1966 and 1971; Fawks 1967; Test 1969; Hamilton 1969; Kleen & Bush 1971). The genetic constitution of Illinois red-shafted flickers is unknown, but presumably includes mainly hybrids between *auratus* and *cafer.* In those cases where red-shafted specimens have been examined 'in hand,' they have invariably proved to be hybrids (Ridgway 1881 and 1914; Lyon 1934 and 1934–1935; Labahn 1941; Coursen 1941; Southern 1962; Test 1969). There is no certain way to differentiate specimens (even in hand) of pure *cafer* from hybrids close to the *(cafer)* parental stock, and virtually every conceivable stage of intermediacy between *cafer* and *auratus* has been recorded in the hybrid zone (Fig. 2). Hybrids close to *auratus* are probably regularly misidentified in the field as *auratus.* The only attempt to determine frequency of hybrid types among Illinois flickers was that of Ridgway (1881), who examined 30 specimens collected in the fall near Mt. Carmel and found only one that showed any sign of hybridization. However, he thought 1 in 200 a more likely incidence of the hybrid phenotype.

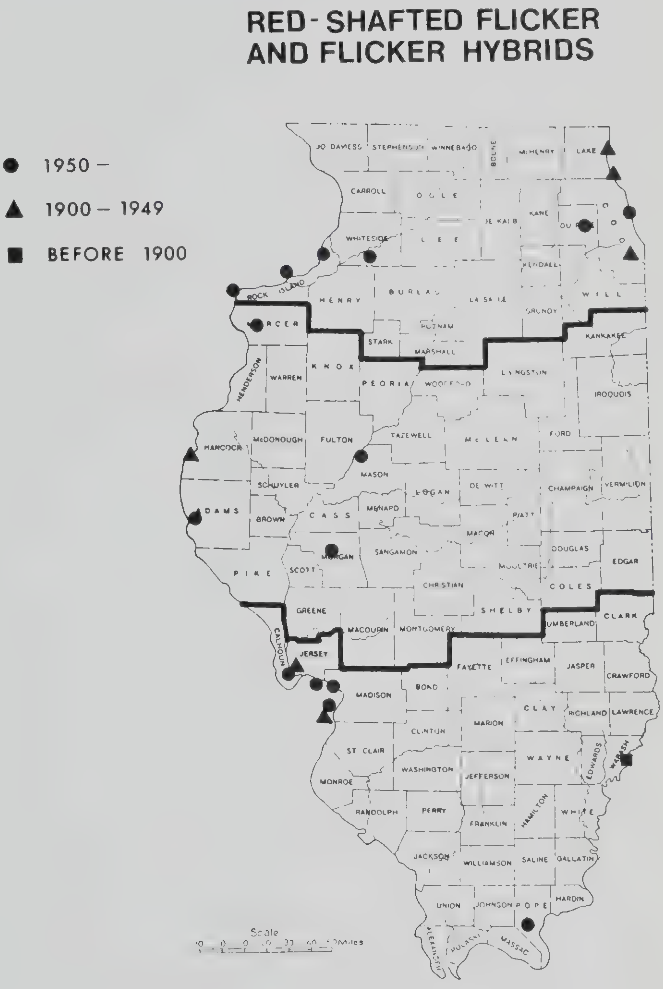
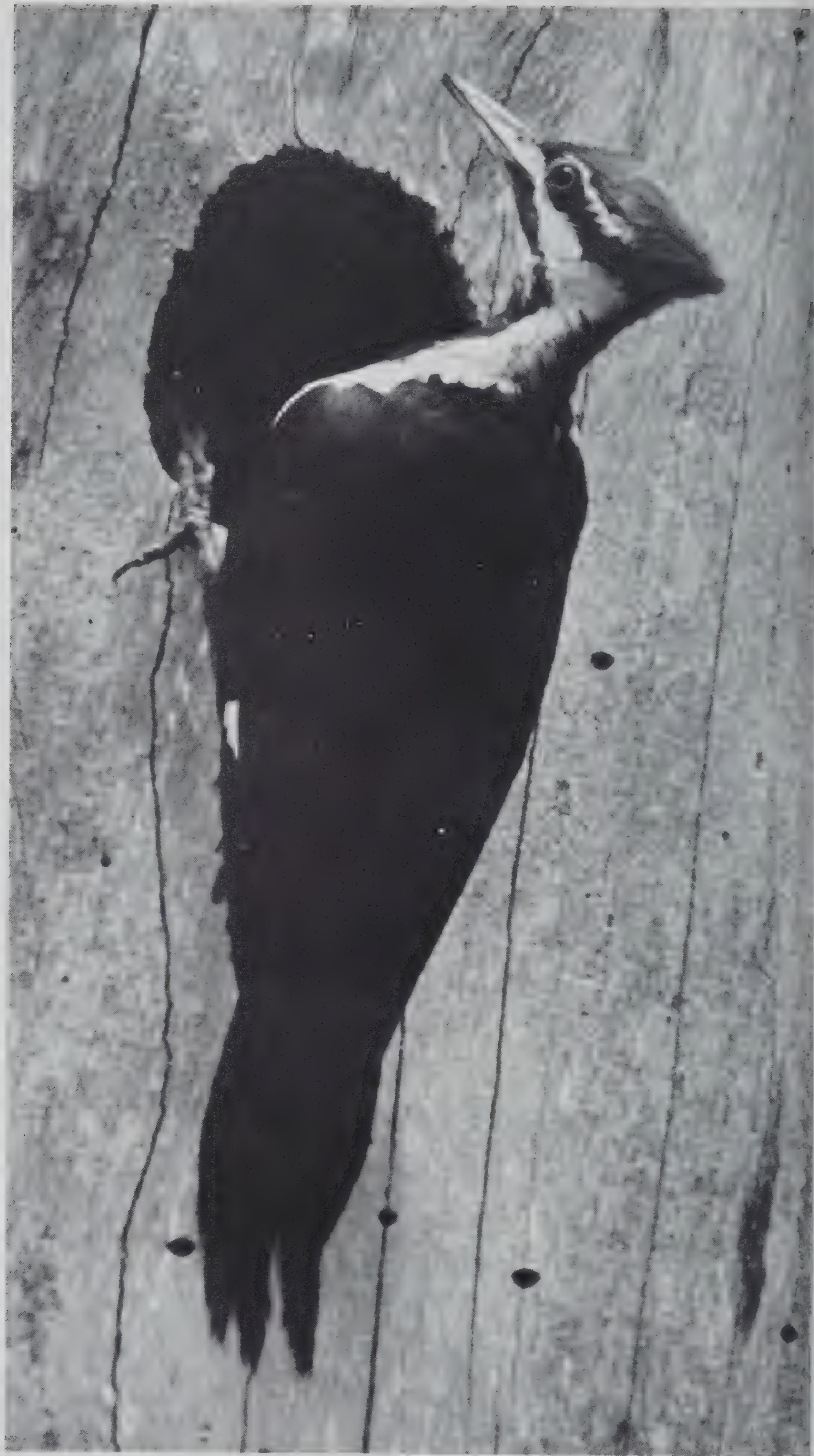


Fig. 7.—Distribution of records of red-shafted and hybrid flickers in Illinois. Heavy horizontal lines separate the three regions of the state.

Red-shafted birds are most often reported in the fall, but a few may overwinter in Illinois (Fawks

Fig. 8.—Pileated woodpecker at its nest. Photo taken in June, 5 miles north of Golconda, Illinois. This large woodpecker is about the size of a crow.



1967; Petersen 1967), especially in the west and southwestern parts of the state.

The dates of reports of "red-shafted" flickers extend from 30 August to 22 May, and the distribution of these records is shown in Fig. 7. The influx of these reddish-shafted birds would seem to indicate that at least some of our winter flickers are from the north or northwest.

There are two obviously erroneous reports of red-shafted flickers in the literature in the Christmas counts, namely the Danville count for 1954 (Anonymous 1955) and the Princeton count for 1958 (Kramer 1959). In both cases 10 red-shafted but no yellow-shafted flickers are listed.

PILEATED WOODPECKER

(Dryocopus pileatus)

(Cover and Fig. 8 and 9)

Distribution

The pileated woodpecker is widely distributed in the forested regions of North America (Fig. 9). The distribution of the pileated, despite its conspicuousness is poorly known in Illinois (Fig. 10).

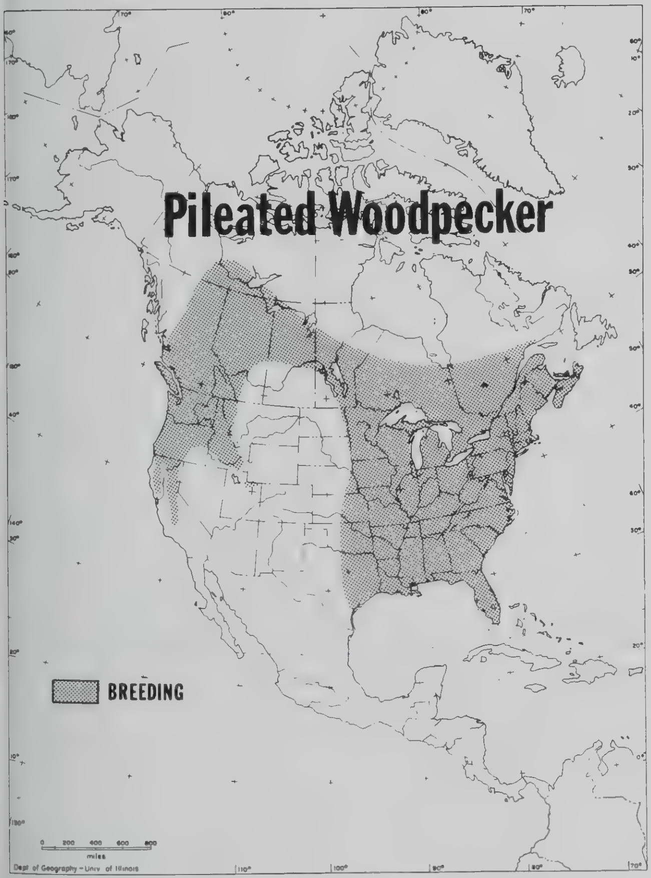


Fig. 9.—General distribution of the pileated woodpecker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat.

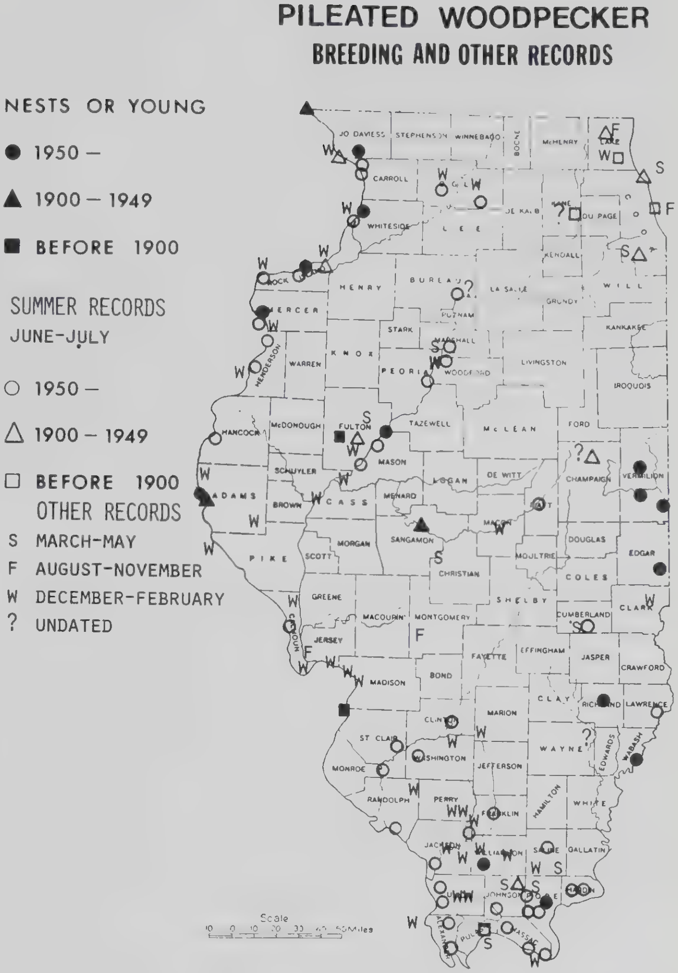


Fig. 10.—Breeding and other records of the pileated woodpecker in Illinois. Since the bird is non-migratory, winter, spring, and fall records have been added to show the pattern of distribution more clearly.

There is no evidence of migration by any Illinois population of the pileated woodpecker. Fluctuations in the spring and fall counts of pileateds (Fig. 11) were probably related to seasonal changes in behavior which affected the conspicuousness of the bird rather than to changes in numbers. Our counts definitely increased at times when the species became noisy, either calling or drumming. In New York, Hoyt (1941) found that pileateds remained in the same area throughout the year. Though we have plotted winter records separately (Fig. 12), in view of the species' sedentary nature the winter records may also be indicative of breeding populations. Consequently, we have included some winter, as well as spring and fall, records in Fig. 10 to provide a more complete picture of the pileated's distribution.

Within historic times the pileated has undergone at least one major cycle of distribution regression and re-expansion in Illinois. The picture is somewhat complicated in that perhaps two distinct populations were involved, the northern *(D. pileatus abieticola)*

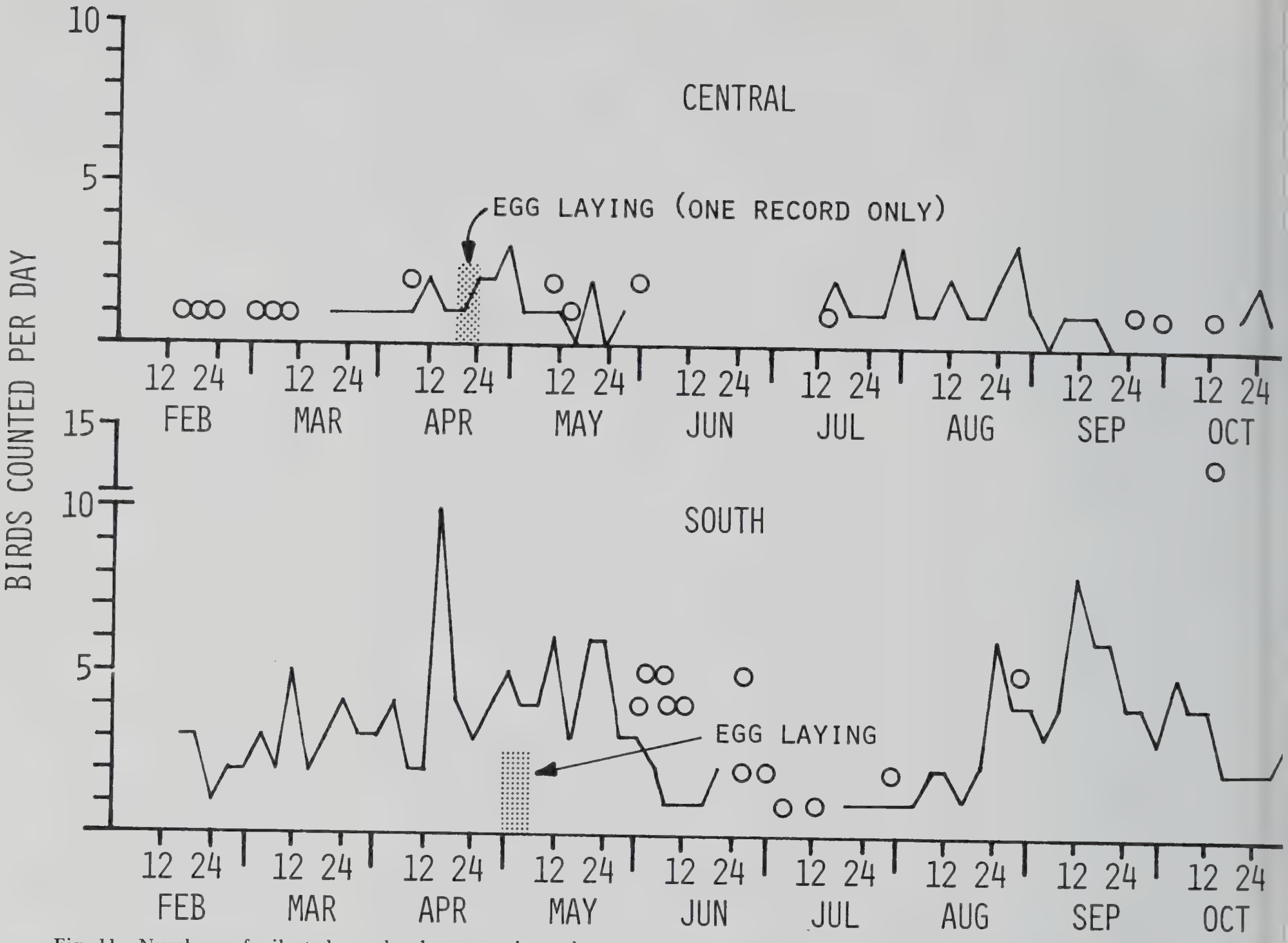


Fig. 11.—Numbers of pileated woodpeckers seen in spring, summer, and fall in central and southern Illinois. The graph line represents the higher daily count of each 4 days made by R. R. Graber in 1967 and 1970 in southern Illinois and in 1969 in central Illinois. Hollow circles represent counts made in other years or by other observers. The egg-laying period (shaded area) shown is very short because of the paucity of records.

and the southern *(D. p. pileatus)* forms of the species. The distribution of the two has never been known except at the northern and southern ends of the state. Kennicott (1853–1854), referring presumably to the northern race, stated that it was formerly not uncommon in Cook County, and forest was sufficiently extensive in the first half of the 19th century to support populations in the northern tier of counties, in Ogle and Kane counties and down the Mississippi valley (Anderson 1970). In northeastern Illinois Nelson (1876–1877) found the pileated to be a rare winter visitant. There is no indication that the northern race has been common in Illinois since then except near the Mississippi, where the species may have sustained itself through the years (Johnson 1936 and 1941).

In the south Ridgway (1881*a*) found the southern pileated to be sixth in abundance of the common species of woodpeckers, though in some localities fourth or fifth, which is very similar to its present ranking. Ridgway (1915) later noted that the pileated population had become much reduced. Vandercook (1919) observed a similar reduction on the Kaskaskia River. In central Illinois Strode (1911) noted the disappearance of the pileated on the Spoon River about 1900. The noted oologist R. M. Barnes (1890 and 1912) did not find the species in Marshall County, nor did Loucks (1891) in the Peoria area. The timing of these observations suggests that all of the authors were witnessing the same change. The cause of the change can only be surmised, but it was probably related to the pileated's requirement of extensive forest habitat and the widespread deforestation of Illinois in the 19th century (Graber & Graber 1963). The declining trend in forest acreage was reversed between 1910 and 1920 (King & Winters 1952), after which pileated habitat probably improved both in quality and quantity. The woodpecker responded, and Jones (1934) made an early reference to its recovery in the St. Louis area, where much earlier Hurter (1884) had found the pileated rare. Musselman (1926) suggested that the pileated

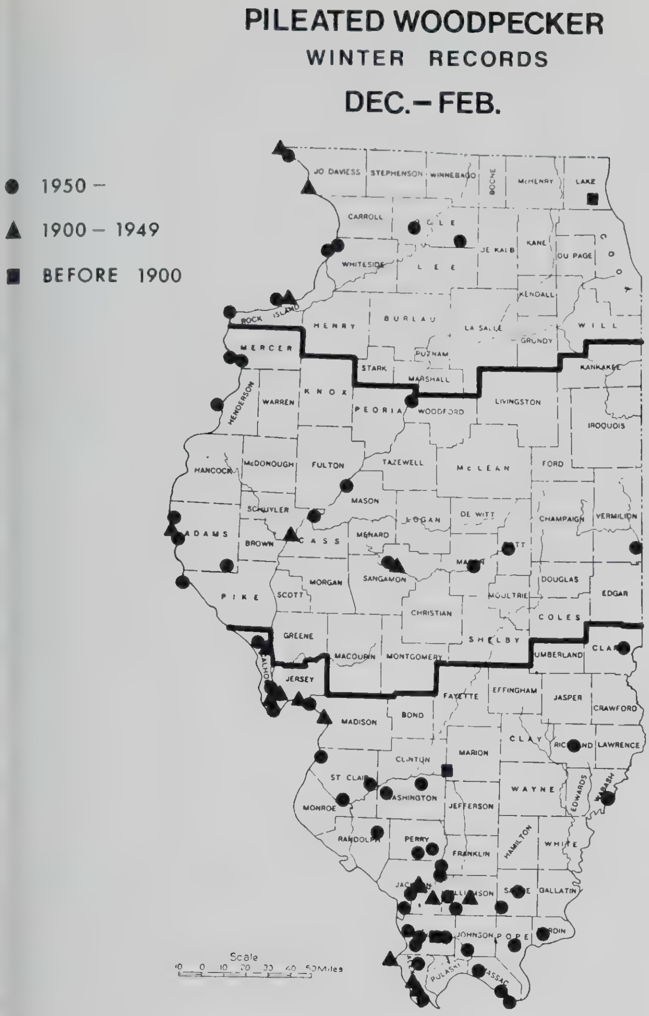


Fig. 12.—Winter records of the pileated woodpecker in Illinois. Heavy horizontal lines separate the three regions of the state.

may never have disappeared from the heavily wooded islands of the Mississippi near Quincy. In the 1950's and 1960's the expanding population of pileated woodpeckers was noted by many observers (Mayfield 1951; Nolan 1955; Petersen 1964) as far north as Rock Island, Whiteside, and Marshall counties (Shaw 1959; Brown 1964; Fawks 1967).

Except for northwestern Illinois, the population expansion appears to have come from the south, i.e., *D. p. pileatus* moving northward along major streams. With the exception of northeastern Illinois, the range of this species is probably now near its maximum 19th century limits, reaching north into Vermilion and Piatt counties in the east, at least to Putnam County on the Illinois River, and the full length of the state on the Mississippi (Fig. 10 and 12). The recent Ogle County records are particularly interesting in view of the complete absence of records for Winnebago County. This suggests expansion from the south along the Rock River, which is thinly forested in many places.

There is no evidence that pileateds ever occupied at any significant or sustained population level the prairie peninsula of eastern Illinois from Kane County south to Iroquois, Champaign, and McLean counties.

Nesting Habitats and Populations

There is a strange dearth of references to the pileated woodpecker's habitat in Illinois. Only Ridgway (1889), in referring to the habitat as "the more heavily timbered portions," and Musselman's (1926) reference to "heavy woods on the Mississippi River islands" indicate the habitat.

Judging from population densities in southern Illinois (Table 4), we conclude that bottomland forest is definitely favored over upland by pileateds. An old bottomland forest, Beall Woods (Wabash County), had the highest population (6.9 pileateds per 100 acres) of any area censused.

Our studies on bird populations in relation to forest vegetation in southern Illinois showed that pileated woodpecker populations were poorest in those bottomland forests with a high Importance (Y) of oak-hickory. The correlation *(r)* between pileated populations and oak-hickory in eight forest study areas was -0.780 ($P = 0.02$). No pileateds were detected in two bottomland forest areas which had oak-hickory Importance values of 64.2 and 97.8. Importance of oak-hickory in woodlands *with* pileateds was 26.5, 32.7, 50.0, 34.8, 28.9, and 31.0 (listed in descending order of pileated populations). Pileated populations were higher in woods having a more even balance between oaks, hickories, maples, elms, *Celtis,*

TABLE 4.—Breeding populations of pileated woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years	Type of Census	Region or County	Reference
Forest (all types, including edge)	340	1–2 (avg 1.5)	1957–1958	Strip	South	Graber & Graber 1963
Virgin bottomland forest	77	3	1948	Map	Sangamon (C) [a]	Snyder et al. 1948
Mature bottomland forest	913	0–7 (avg 1.2)	1974–1975	Strip	South	This paper
Mature upland forest	479	0–0.5 (avg 0.2)	1974–1975	Strip	South	This paper

[a] C refers to the central region of Illinois, as shown on winter distribution maps, e.g., Fig. 5.

ashes, and sweet gums. There was a positive correlation between the number of pileated woodpeckers and the number of large (over 22 inches DBH) *Celtis* ($r = 0.894$, $P < 0.01$) in bottomland tracts.

It is not surprising that pileated populations were much lower in upland forest (Table 4), where oak and hickory are the characteristic dominants. The only upland woods (of five censused) having a measurable pileated population within the census transect was adjacent to a bottomland with a high population of pileateds. This upland woodland also had a more balanced tree composition than most uplands, with the Importance of oak-hickory being only 39.8. For the upland study areas lacking pileateds, oak-hickory Importance ranged from 54.5 to 87.0. Where pileateds are found in hill land, they frequent the valleys and ravines, where oak-hickory usually constitutes less than 40 percent of the tree flora (Voigt & Mohlenbrock 1964).

How large a forest tract is required to sustain a pileated population is unknown. No measurements of pileated populations exist for northern Illinois. Territory size has not been measured in any Illinois population of pileateds.

We have nest-site data for only 12 pileated nests in Illinois. All were located in live sycamores or dead trees and trunks. Heights of nests ranged from about 10 to 90 feet (Strode 1911), being higher in northern and central Illinois (average for three nests: about 60 feet if the 90-foot figure is true), than in the south (average for six nests: about 25 feet).

Nesting Cycle

Nothing has been recorded on the nesting cycle of the pileated woodpecker in Illinois. For data on populations elsewhere see Hoyt (1941 and 1944), Hoyt (1957), and Kilham (1959).

In southern Illinois pileateds become particularly noisy in March, loudly calling and giving their distinctive "drum roll." This behavior may mark the onset of nesting activity. Kilham (1959) has observed mating in Maryland in late March. Off and on through most of the year the commonest calls heard suggest alarm—loud "kuk-kuk" notes, sometimes rising and slurred into a high cackling sound. Also through the year, but more frequently in the spring, we hear the loud, high, rolling "song" suggestive of the flicker's "song" but much more clarion.

On the basis of fledging dates and incubation (18 days) and nesting (26 days) periods given by Hoyt (1944) and Hoyt (1957), we conclude that egg laying occurred about 20 April at one nest in central Illinois and 1–6 May at two nests in southern Illinois. We would expect laying to begin much earlier in south than in central Illinois.

While photographing pileateds at a nest in Pope County, we observed a pair trade places in brooding the young. The male was in the cavity when the female alighted quietly on the back side of the nest tree. Within a few seconds the male left silently. As there had been no vocalization or tapping and as the male could not have seen the female, he must have heard her land on the trunk. The female waited for about 1 minute after the male departed, then came around to the nest entrance and went in. Both adults also fed the young, bringing food so enclosed in their bills that we could not identify it. When the adults landed on the nest tree, we could hear the young utter a buzzy whirring sound audible at least 25 feet from the nest.

There are no Illinois data on nesting success or productivity.

Fall and Winter Populations

The dispersal of pileated woodpeckers in fall or winter has not been substantiated with banded birds, but there is other evidence of some movement—notably the occasional appearance of pileateds in urban areas in winter and a slight increase in the pileated population in upland forest and a decrease in bottomland forest, compared with summer levels (Tables 4 and 5).

The ratio of our spring (March–May, inclusive) to fall (August–October) counts of pileateds in southern Illinois was 1.0 (spring) to 1.2 (fall), suggesting modest productivity in summer. There is a definite resurgence of drumming by pileateds in September and October, making them conspicuous and probably affecting the counts, but as there is also much drumming in spring, the effect may be evened out. Surprisingly, our data show little difference between summer and winter in the total population of

TABLE 5.—Winter populations of pileated woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Forest (all types, including edge)	241	1	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	0	1957–1958	Strip	South	Graber & Graber 1963
Mature bottomland forest	1,398	0–7 (avg 0.9)	1974–1976	Strip	South	This paper
Mature upland forest	772	0–2 (avg 0.3)	1974–1976	Strip	South	This paper

pileateds when we apply density figures to the appropriate habitat acreages (Graber & Graber 1976). Summer populations were slightly higher, perhaps indicating that most of the production of young has occurred by June.

Cooke (1885*b*) saw 5–15 pileateds per day in winter in Union County—a high population area, where we have seen lower numbers (peak: 7 per day) in recent years.

Winter pileated woodpecker populations are highest in bottomland forests with large trees (Fig. 13). In seven of eight bottomland tracts that we studied in southern Illinois a positive correlation existed between the number of large trees (over 22 inches DBH) and the number of pileateds encountered per hour of censusing ($r = 0.960$, $P < 0.001$). A positive correlation also appeared between pileated numbers and the Importance (see Introduction) of *Celtis* ($r = 0.779$, $P < 0.05$) and *Ulmus* ($r = 0.702$, $P = 0.05$). As in summer, there was a negative correlation between numbers of pileateds and the Importance of oak-hickory. Habitat preference apparently does not change greatly between summer and winter in this species in contrast to those of most other woodpeckers.

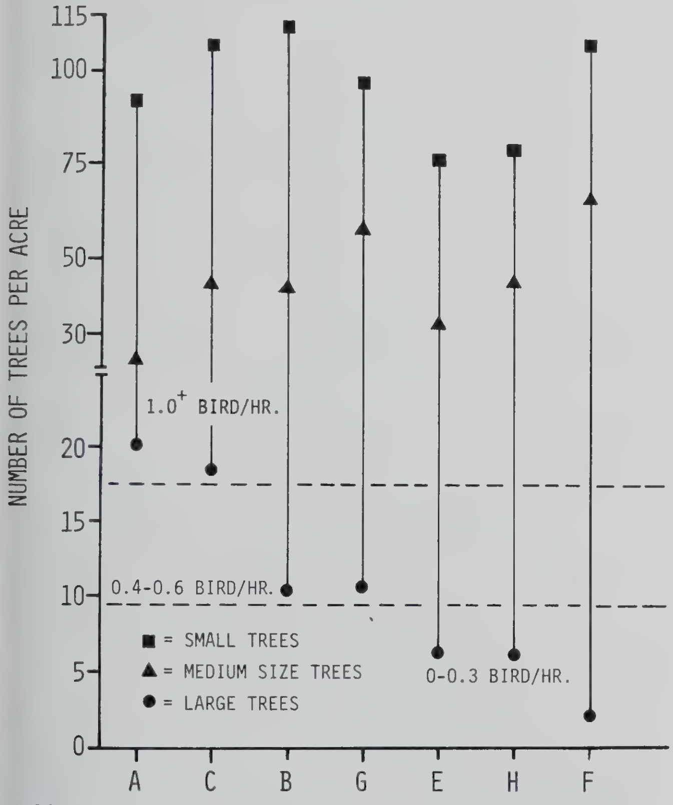


Fig. 13.—Correlation between winter numbers of pileated woodpeckers and sizes of trees. Each vertical line represents a separate bottomland forest. The square, triangle, and dot on each line show size classes of trees with the square representing trees 4–10 inches DBH; the triangle, trees 10–22 inches DBH; and the dot, trees over 22 inches DBH. The horizontal dash lines divide population levels of pileated woodpeckers. Letter designations refer to specific forest tracts identified in the introduction.

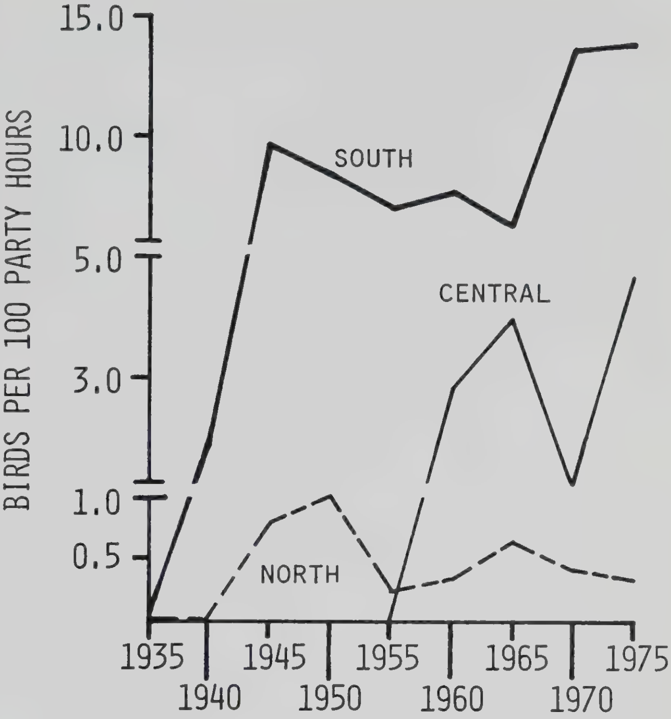


Fig. 14.—Pileated woodpeckers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average.

The Christmas counts for the pileated woodpecker show the highest annual variation of those for any of the common woodpeckers. Annual variation in the counts for the past 10 years ranged from 0 to 279 percent (mean = 74 percent) in northern Illinois, 14–160 percent (mean = 70) in central Illinois, and 11–648 percent (mean = 114) in the south. Our own winter censuses show only about 25 percent annual variation. The Christmas counts show a population gradient, declining from south to north (Fig. 14). The species was first detected on a count made much later in central Illinois (1955) than those on which it was first found in the north and south (1940 and 1928, respectively), possibly reflecting the expansion of two populations, one from the north and another from the south with the central region being the last reached from either end.

We have but one observation on roosting by a pileated woodpecker. At 4:25 p.m. CST on 22 November in Pope County, a pileated entered a roosting cavity about 25 feet high in a dead stub, which had also been used during the summer as a nesting site (in a different cavity 11 feet high).

Food Habits

The only Illinois reference we have found to the food of the pileated woodpecker is that of Cooke

(1885*b*), who found that winter specimens from Union County were filled with ants. The stomach of a March (1977) specimen from Vermilion County was packed with carpenter ants (*Camponotus herculeanus*). Beal's (1911) study of 80 North American specimens also showed ants to be important in the diet. He found the pileated's food to be about 73 percent animal and 27 percent vegetable matter. The animal food was about 40 percent ants and 22 percent beetles—especially the larval stages of wood borers of the families Cerambycidae, Buprestidae, and Elateridae, probably taken mainly from dead or decaying wood. The ants also were of the larger species found on and in decaying wood. In one stomach Beal counted 2,600 ants. Other animal food included flies, caterpillars, grasshoppers, and termites. Musselman (unpublished notes 1968) observed pileated woodpeckers feeding on suet. He also witnessed a red-headed woodpecker chasing a pileated from the suet feeder.

The vegetable food was virtually all wild fruit, such as hackberry, smilax *(Smilax)*, blackberry, sumac and poison ivy, holly *(Ilex)*, grape, dogwood, tupelo, persimmon, sassafras, elderberry *(Sambucus)*, and haw *(Viburnum)*, all common plants in Illinois.

In their search for borers, pileateds often make distinctive large holes (Fig. 15) in infested trees. We have noted these characteristic holes most often on sassafras, box elder, ash, cottonwood, Kentucky coffee tree, and beech.

Beal (1911) concludes his remarks on the pileated with an appeal for the species' protection. Unfortunately, pileated woodpeckers are often shot, because of their large size, by ignorant hunters. Musselman (1933) refers to four being shot in 1 week near Quincy. Pileated remains have been detected among Indian middens dating back perhaps 10,000 years (Parmalee 1959; Noyes & Hill 1974).

Specimen Data

Because of the paucity of preserved specimens, it is still uncertain whether there are (or were) two distinct populations of pileated woodpeckers in Illinois. We have examined 20 Illinois specimens, of which 18 were in adult (i.e., not obviously immature), not obviously worn, plumage (Table 6). Three of the male specimens—all collected before 1900—fall within the size range of the northern form, *Dryocopus pileatus abieticola,* as given by Ridgway (1914). The distribution of these specimens indicated a range for that race of extreme northern Illinois, south along the Mississippi valley to at least Hancock County. These large males also (as in *abieticola*) have a slightly grayer tone of body plumage than have specimens from southern Illinois. All other Illinois specimens—central and southern Illinois, male and female—fall within the size range of *D. p. pileatus* (Table 6 and Ridgway 1914). These central and southern

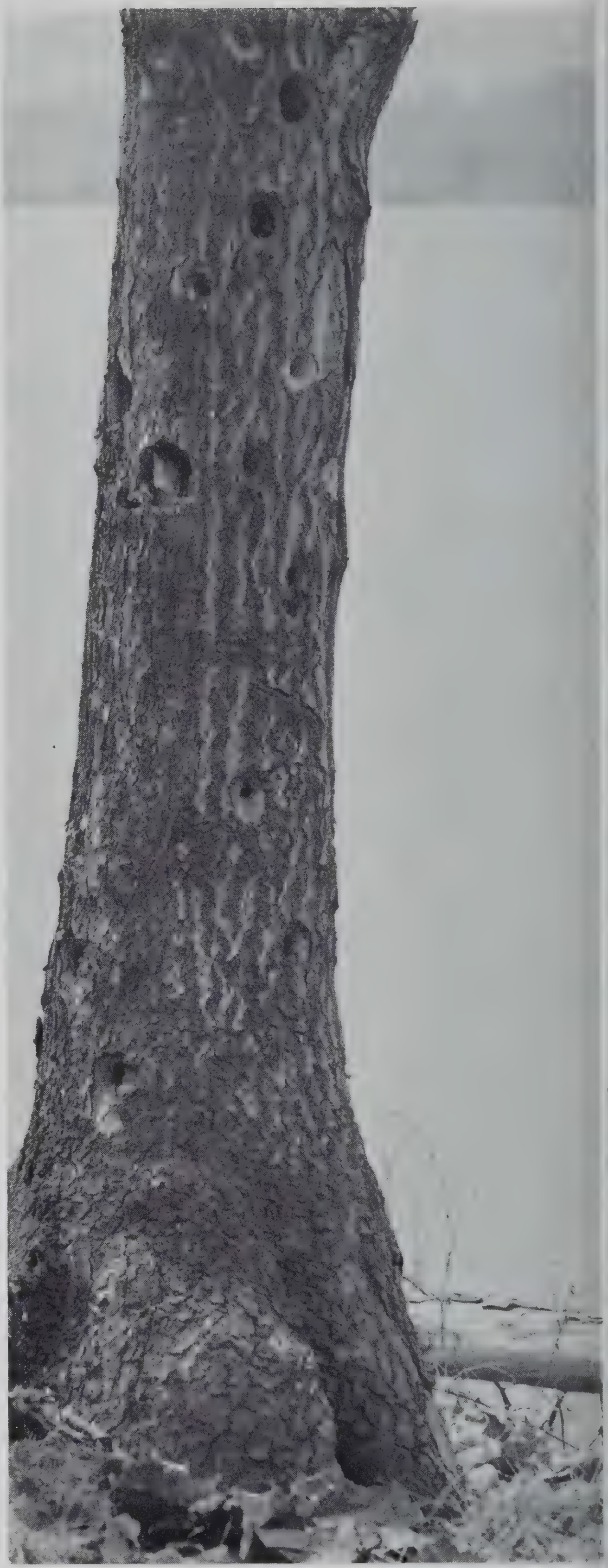


Fig. 15.—Typical pileated woodpecker work on a red oak on the Ohio River bank at Golconda, Pope County, Illinois.

TABLE 6.—Measurements of Illinois specimens (plus one from adjacent Indiana) of pileated woodpeckers, excluding obviously worn, molting, and juvenile specimens.

Region of Illinois	Months	Number of Specimens	Sex	Wing (Chord) in mm			Tail Length in mm			Culmen (from Naris) in mm		
				Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
North and Mississippi valley of Central	Nov.–Mar.	4	M	229–245	237.1	6.51	153–163	159.3	4.86	43–53.5	48.2	4.15
South and Central (except Mississippi valley)	Sept.–May	7	M	217–234	224.7	6.24	148–157	153.1	4.25	42–47	44.9	2.41
South and Central (except Mississippi valley)	Oct.–May	8	F	213–226	218.3	4.17	140–152	147.2	3.58	36–43	40.7	2.07

Illinois specimens have almost the same size range as have Kentucky specimens (Mengel 1965) if we use mean wing length ± 3 SD to indicate the maximum range for the population. Within this maximum range, however, would be all of the Illinois specimens but one, including even the northern specimens. We have seen no recent (since 1900) specimen showing the characters of *abieticola*.

We have found weight data on only four adult specimens—three females: an April specimen from Cumberland County, 262.2 grams; a May specimen from Sangamon County, 237.4 grams; and one March specimen from Pope County, 223.5 grams. The fourth, a male, was a March specimen from Vermilion County that weighed 278.6 grams. An immature female from Jackson County, probably near the end of the post-juvenile molt, weighed 209.5 grams.

RED-BELLIED WOODPECKER
(Centurus carolinus)

(Fig. 16 and 17)

Spring Populations

Do red-bellied woodpeckers migrate in Illinois? A few authors have suggested that they do (Nelson 1876–1877; Cooke 1888; Smith & Parmalee 1955). Hess (1910) admitted that he was uncertain about the matter, and there are no published records to indicate that the migration has been observed directly. We have seen what we assumed to be diurnal migration of a few red-bellied woodpeckers on the "blue jay routes" of the Mississippi and Ohio valleys, but only in fall (Fig. 18). There is no positive evidence of nocturnal migration by the species (see Fall Migration). Red-bellied woodpeckers do not vacate any sizeable part of Illinois in winter, and the spring populations do not show a pronounced migration peak like those of the strongly migratory flicker and red-headed woodpecker (Fig. 3 and 26).

The highest spring counts of red-bellies have been recorded in February and March (Fig. 18), months for which we have only fragmentary data. If a migration occurs in that period, it is conspicuously earlier than the spring flights of the red-headed woodpecker and the flicker. Fluctuations in spring populations of the red-belly could be accounted for by behavior other than migration, but students should continue to look for the migration. As the red-belly is increasing its populations northward, it is possibly now evolving migratory behavior.

Distribution

There is evidence that the red-bellied woodpecker has been slowly expanding its range northward in Illinois for more than a century, and it has met with increasing success in the past half century. Within historic times it has been abundant in southern Illinois (Ridgway 1881*b*) with the population developing later in central and northern Illinois. Kennicott (1853–1854) made no mention of the species in northeastern Illinois, where Nelson (1876–1877) called the species rare in summer but not uncommon during migration. Later, Woodruff (1907) considered it only a rare migrant in the Chicago area. Farther south the renowned oologist R. M. Barnes (1890) had never found a red-bellied woodpecker nest in Marshall County, and Loucks (1892 unpublished manuscript) found the species rare in Peoria and Tazewell counties. However, by 1905 Barnes (unpublished note 1905) observed it increasing, and by 1912 the species had become a common nester in the Illinois River bottoms of Marshall County (Barnes 1912). Away from the Illinois River in Logan County red-bellies were still rare in 1918 (Du Bois 1918). The range expansion appeared to progress even better on the Mississippi than in the Illinois River valley, as Schafer (1918) was seeing 6–10 red-bellies per day during February and March, 1918, near Port Byron. He also recorded red-bellies on 6 of 10 breeding bird censuses between 1914 and 1923 (Table 7). At the same latitude on the eastern side of the state at Orland (Cook County), red-bellies were still uncommon as late as 1947 (Coursen 1947) though they were believed to be increasing (Moseley 1947). Charles T. Clark (personal communication 1975) noted that the red-bellied woodpecker population in Cook County began an accelerated increase in 1956. Our cross-country census of 1957–1958, which covered 177 acres (16.2 miles) of forest in the two northern

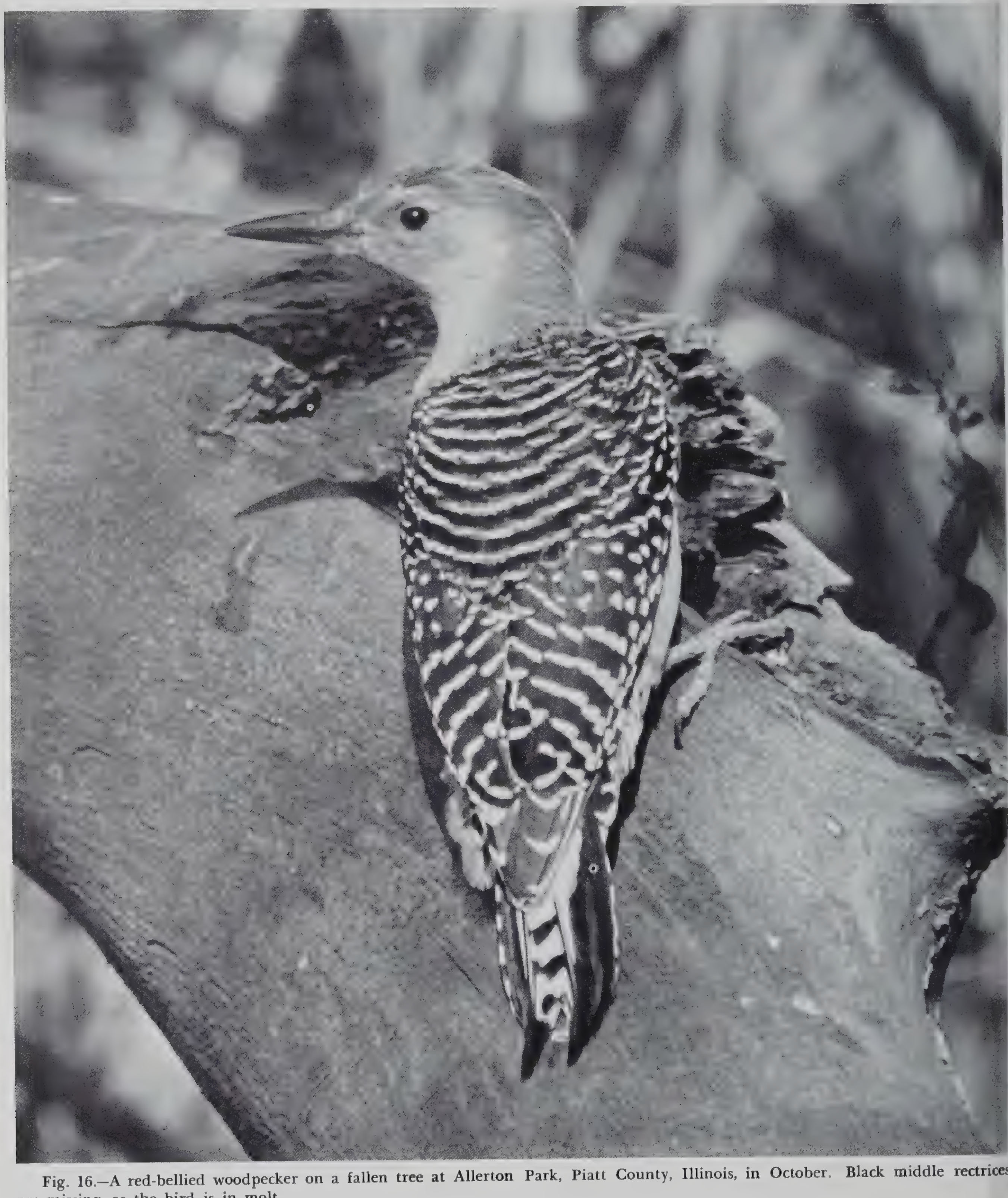


Fig. 16.—A red-bellied woodpecker on a fallen tree at Allerton Park, Piatt County, Illinois, in October. Black middle rectrices are missing, as the bird is in molt.

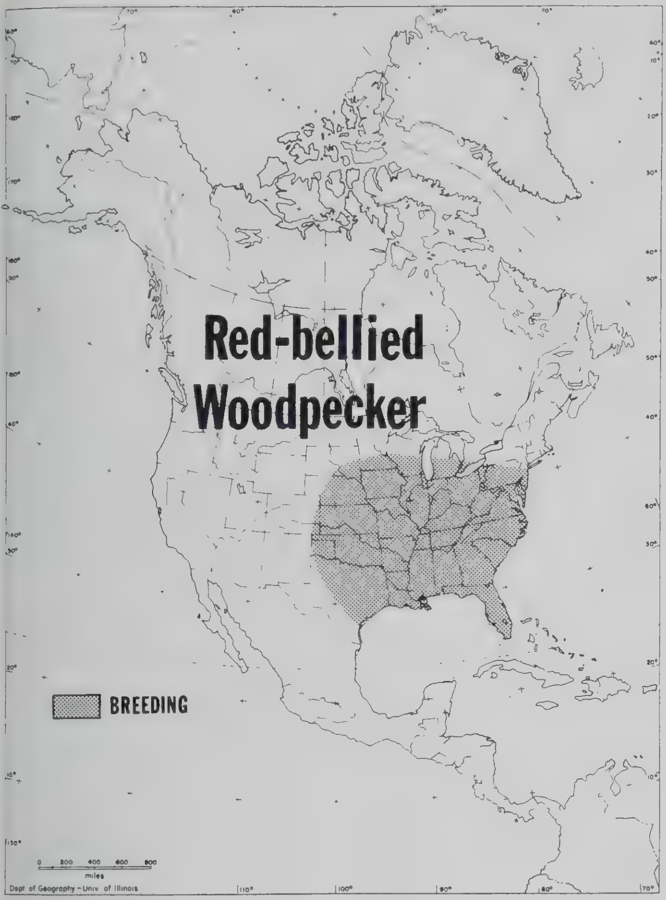


Fig. 17.—General distribution of the red-bellied woodpecker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat.

tiers of counties, did not intercept a red-belly within the transect, but the census did not include extensive riparian forest. There is a need for more recent population data on the red-belly in the north to compare with those of Schafer (Table 7). The picture of the red-bellied woodpecker's range expansion in the north appears to be one of surges and declines, with larger populations along the major rivers. The population is apparently still very thin in the north by comparison with that of central Illinois.

The red-bellied woodpecker is an eastern U.S. species (Fig. 17). In Illinois it probably nests in every county though records are still lacking for many (Fig. 19). In addition to the records plotted in Fig. 19, there is a definite nest record for Lake County for which the specific locality was not given (Goelitz 1917).

Nesting Habitats and Populations

In summer the red-bellied woodpecker is essentially a bird of the forest interior (Kendeigh 1944), and Silloway (1922 unpublished manuscript) found it most frequently in large trees of the interior. In southern Illinois red-bellies make some use of shrub habitat and pasture for foraging (Table 7). Red-bellies do not generally inhabit residential areas in summer (Ridgway 1887). They occupy both bottomland and upland forest, but most authors indicate that bottomland is the preferred type (Nelson 1877; Gates 1911; Kumlien & Hollister 1951). In east-central Illinois Hess (1910) found red-bellies only in the wilder timbered bottoms at a time when the species was still expanding its population in that region. Both Barnes (1912) and Yeager (1955) noted that red-belly populations increased where timber was flooded enough to kill trees.

At Morton Arboretum, apparently in upland habitat, Swink (1959) found oaks, especially white oaks, to be the most frequent perching sites for red-bellies. By contrast, Kumlien & Hollister (1951) specifically mentioned maple and ash, in preference to oak, as habitat for red-bellies in heavy bottomland timber.

We measured summer populations of red-bellied woodpeckers in five upland and eight bottomland woods in southern Illinois in 1974 and again in 1975. No correlation was found between numbers of these birds and density or basal area of living or dead trees of any genera or species with one exception. There was a positive correlation between the number of red-bellied woodpeckers per 100 acres in seven of the bottomland woods and the Importance (Y) of maples ($r = 0.793$, $P < 0.02$), particularly silver maples ($r = 0.804$, $P < 0.02$). The highest correlation among different size groups was for maples 10–18 inches DBH ($r = 0.711$, $P < 0.05$). We found no maples in one bottomland woods, which had an average population of red-bellied woodpeckers (see below). The red-belly appears to occupy the maple-ash areas of bottomland woods, while the red-head occupies the oak portions of such woodlands. In a central Illinois woodland, Williams (1975) found that red-bellied woodpeckers spent much time foraging in silver maples, whereas red-heads in the same woodland spent much of their time in oaks. Willson (1970) observed conflicts between the two species in a central Illinois woodland and observed that the red-head usually dominated.

The highest recorded Illinois population for a significant habitat sample was 23 red-bellies per 100 acres in a virgin floodplain elm-maple forest in Sangamon County (Table 7). High populations in individual forest tracts of 50 or more acres were 9–23 birds per 100 acres in both central and southern Illinois bottomland. Average populations from place to place and year to year in bottomland forest were about 6 red-bellies per 100 acres, and average populations in uplands were only slightly lower—4.5 per 100 acres.

Calef (1953*a*) and Stickel (1965) suggested that red-bellies had notably large territories and home ranges. In a mature bottomland forest in McLean County Calef (1953*a*) measured five territories, which

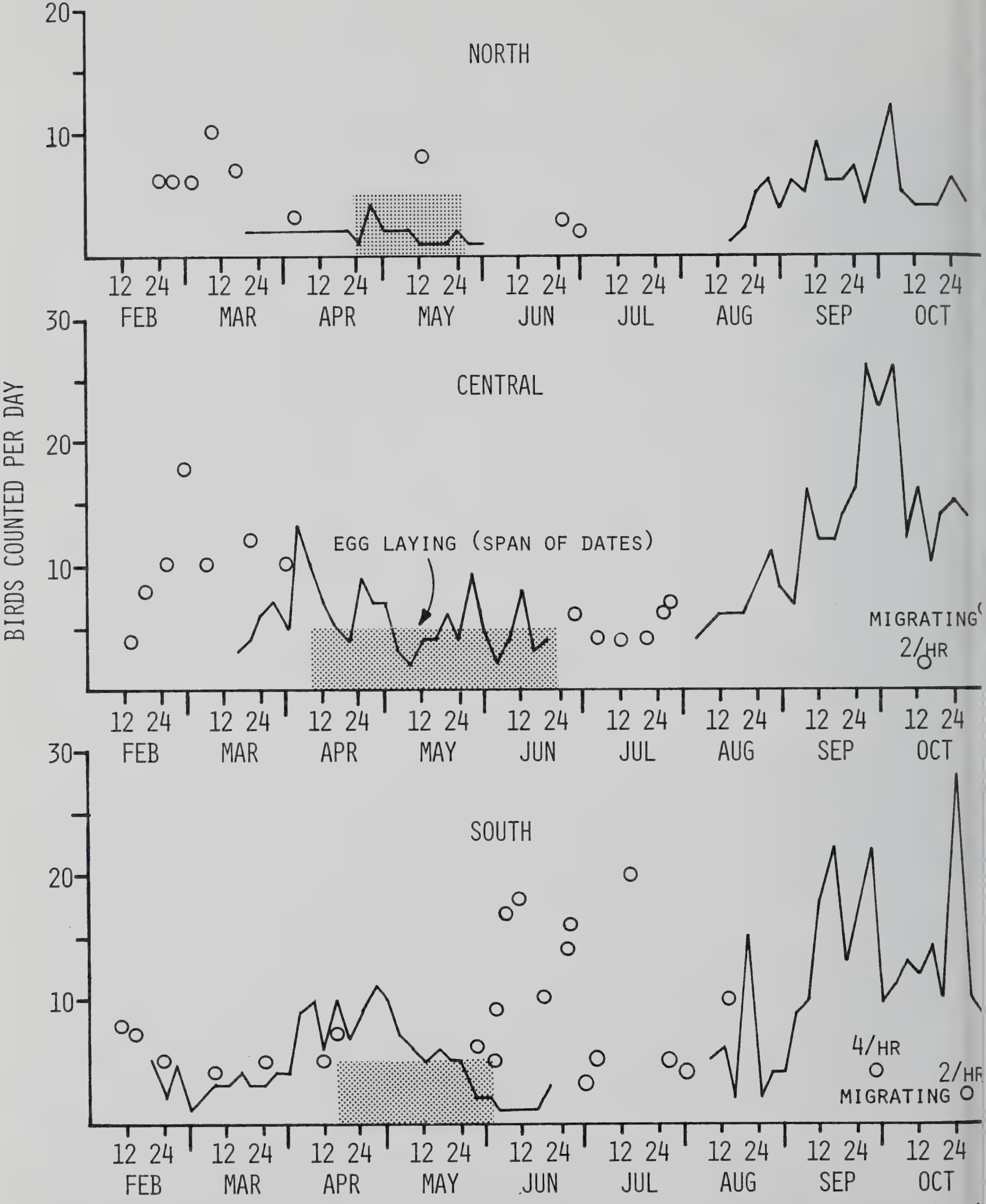


Fig. 18.—Egg-laying season and numbers of red-bellied woodpeckers seen in the spring, summer, and fall in the three regions of Illinois. The spring and fall graph lines represent the higher count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

TABLE 7.—Breeding populations of red-bellied woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Oak-maple forest	55	0–4 (avg 2.9)	1927–1947	Map	Champaign (C) [b]	Kendeigh 1944, 1948*b*
Oak-maple forest	55	4–18 (avg 7.9)	1948–1974	Map	Champaign (C)	Kendeigh 1960*b*; Kendeigh & Edgington 1974
Oak-maple forest	64	6	1943	Map	Champaign (C)	Johnston 1947
Forest (all types, including edge)	214	4–5 (avg 4.7)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	60	5	1907, 1909	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	340	4–6 (avg 5.0)	1957–1958	Strip	South	Graber & Graber 1963
Mature upland forest	479	0–9 (avg 2.7)	1974–1975	Strip	South	This paper
Mature bottomland forest	913	0–11 (avg 4.0)	1974–1975	Strip	South	This paper
Virgin floodplain forest	77	23	1948	Map	Sangamon (C)	Snyder et al. 1948
Virgin floodplain forest	50	12	1947	Map	Piatt (C)	Fawver 1947*b*
Mature bottomland forest	63	11	1950–1951	Map	McLean (C)	Calef 1953*a*
Grazed bottomland woods	53	7	1955	Map	Macon (C)	Chaniot & Kirby 1955*b*
Forest (unspecified)	20	0–10 (avg 3.3)	1914–1916		Rock Island (N)	John J. Schafer (unpublished notes 1914–1923)
Forest (unspecified)	54	0–9 (avg 4.3)	1917–1923		Rock Island (N)	John J. Schafer (unpublished notes 1914–1923)
Upland second-growth oak-hickory	56	4–7 (avg 4.8)	1941–1942, 1944	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*, 1944*b*
Upland second-growth oak-hickory	46	4	1948	Map	Sangamon (C)	Robertson & Snyder 1948
Upland oak-hickory	24	17	1967	Map	Hancock (C)	Franks & Martin 1967
Second-growth hardwood	15	13	1937–1938	Map	Rock Island (N)	Fawks 1937, 1938
Shrubby field and forest edge	60	2	1949	Map	Richland (S)	Stine 1949
Shrub area	39	5	1909	Strip	South	Graber & Graber 1963
Shrub area	129	0–3 (avg 1.5)	1957–1958	Strip	South	Graber & Graber 1963
Pasture	601	(+) [c]	1907	Strip	South	Graber & Graber 1963
Pasture	120	0–1 (avg 0.8)	1957–1958	Strip	South	Graber & Graber 1963

[a] All figures were converted to birds per 100 acres (number of territorial males or nests × 2).

[b] S refers to the southern region of Illinois, C to the central, and N to the northern region, as shown on winter distribution maps, e.g., Fig. 5.

[c] The plus symbol (+) indicates fewer than one bird per 100 acres.

ranged from 2.1 to 5.2 acres and averaged 3.5 acres. In Piatt County Fawver (1947*b*) measured three territories, which averaged 6.1 acres in virgin floodplain forest, and Allison (1947) measured two territories, which averaged 4.4 acres in mature upland forest. There are no data on territory size for southern Illinois. Reller (1972) suggested that red-bellies tend to forage outside the woods in which they nest, perhaps as a mechanism for reducing competition.

Bush (1934–1935) pointed out that an inverse relationship exists between red-belly and red-head populations after the nesting season (see Winter Populations), and the relationship of even the summer populations shows something of the same tendency. The ecological distribution of the two species in summer and winter shows that they tend to complement one another. The broad occupancy of woody habitats by red-heads in summer contrasts to the relatively narrow occupancy of certain forests by the red-belly, while in winter the situation is reversed, the red-belly taking on a broad ecological distribution and the red-head becoming much more restricted to forest. The highest breeding population of red-bellies we found in southern Illinois was in a forest that had no red-heads. Even the geographic distribution of the two populations tends toward segregation, with generally more red-bellies in the southern part of the state, and more red-heads in the northern part of Illinois. Willson (1970) has also observed segregation of the sexes, during foraging, within a red-bellied woodpecker population.

The published and unpublished data presently available to us on nest sites include information on only 31 nests of the red-belly, mainly in central Illinois. Virtually all nests were in dead trees or stubs or dead branches of live trees—notably oak, willow, elm, maple, ash, cottonwood, poplar, sycamore, basswood, and locust (species not specified). In east-central Illinois red-bellies more often used dead limbs of live trees, whereas red-heads nested in the trunks of dead trees (Reller 1972). Heights (usually estimated) of nests varied from 3 to 90 feet and averaged 32 feet. Reller (1972) observed that nests in Piatt and Champaign counties most often faced south or west.

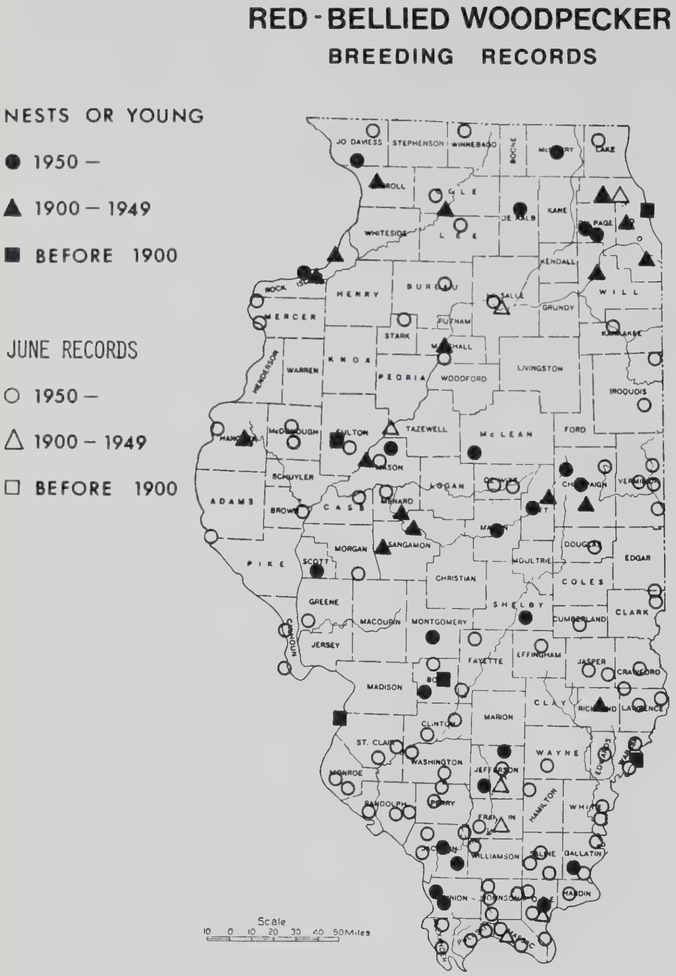


Fig. 19.—Distribution of breeding records of the red-bellied woodpecker in Illinois. Hollow symbols represent birds seen or heard during June.

Nesting Cycle

Most of what is known about the nesting cycle of the red-bellied woodpecker in Illinois comes from a study in southern Illinois by Stickel (1965) and a study in central Illinois by Reller (1972). These authors and Kilham (1958 and 1961) also discuss vocalization of the species.

Adult red-bellies separate after the breeding season, but remain somewhat territorial and often occupy areas different from the nesting territory (Weise 1951; Stickel 1965). In southern Illinois pairs may be formed as early as January or as late as late April. In central Illinois courtship activity involving aggregations of up to five birds and much calling and chasing has been noted in the last half of February and early March, and breeding territories appeared to be established by the last of March (Allison 1947; Fawver 1947*a*).

Pair formation centered about the selection and excavation of the nest cavity, in which the male took the lead (Stickel 1965). At Carbondale the excavation of cavities began in January and continued, off and on, into April. In Piatt County Fawver (1947*a*) observed the work of excavation during the first 3 weeks of April. The sizes of nest cavities of red-bellied woodpeckers have not been recorded in Illinois.

Bent (1939) gives egg dates for the red-belly in Illinois from 1 April to 3 June (locality unspecified). In central Illinois egg laying occurs from at least 9 April through 23 June (Fig. 18). No nest is constructed within the cavity, the immaculate white eggs being laid, one per day on consecutive days, on the floor of the cavity. The red-belly, in contrast to the flicker, is a determinant layer (Stickel 1965). Clutch-size data representing 16 nests, mainly from old literature and museum records, showed this distribution: five eggs, 10 nests; four eggs, 4 nests; three eggs, 2 nests.

Stickel (1965) observed that incubation started with the third egg laid, and required 11–12 days. In case of nest failure, a second clutch was laid within 12 days, usually in a different cavity. Nestling life lasted at least 22 days, and as long as 27 days, but usually 26 days. Both sexes shared in the incubation and care of the young but with considerable variation from pair to pair. At night the male usually incubated or guarded the nest (Stickel 1965). Exclusive of cavity excavation, the cycle required about 41 days, assuming the onset of incubation with the third egg, as observed by Stickel (1965). The food of the nestlings was not specifically determined but included both insects and fruit. At the Carbondale study area Stickel (1965) observed the adults bringing food to nestlings in different nests at average rates varying from as few as four trips between 1 p.m. and 2 p.m. to as many as 16 trips per hour around 9 a.m.–10 a.m. The work of feeding was shared about equally by the adults.

Quantitative data on nesting success have not been recorded for any Illinois population of red-bellies. At one nest Stickel (1962) found a large black rat snake *(Elaphe obsoleta)* which had eaten nestlings and an unhatched egg.

Fledglings at Carbondale remained near the nest (within 100 feet) for at least 2 days, after which they began to follow the parents. Juveniles appeared to be independent about 6 weeks after fledging, when they apparently left the area (Stickel 1965). Intensive study of this species in Maryland by Kilham (1961) revealed no evidence of double broodedness, and single broods are probably the rule in Illinois also.

Like other woodpeckers, red-bellies roost singly in cavities, except for new fledglings, which roost in the open and must learn the adult behavior. Again, Stickel (1964) has provided most of the Illinois data on the subject. He observed that, though there is a surplus of cavities from the nesting season, both sexes excavate additional cavities at other seasons. Such roosting cavities are shallower than nest cavities. Nest chambers were also used for roosting, particularly by males. Birds change roosting cavities often and sometimes return to a formerly used cavity.

Competition for cavities in the nesting season has not been considered a critical problem for the red-belly in Illinois. Reller (1972) pointed out that differences in nest-site selection have reduced competition between red-heads and red-bellies. In the south Stickel (1963) witnessed strife at a nest tree between aggressive hairy woodpeckers and a pair of red-bellies, which remained relatively passive toward the hairies but vigorously attacked a flying squirrel in the same tree. Stickel (1963) also observed aggression of red-bellies toward flickers at both nesting and roosting cavities. In a screech owl nesting and roosting box in Pope County, we found numerous feathers of red-bellied woodpeckers, apparent victims of the owl. Brown & Bellrose (1943) also recorded such predation.

Fall Populations

After the breeding season, strife between red-bellied and red-headed woodpeckers increases considerably, as red-heads turn from more intraspecific aggression to interspecific aggression directed especially toward red-bellies (Reller 1972). Food is a probable source of contention, as both species store mast. In such encounters the red-head is almost always dominant (Ridgway 1889; Schafer 1918; Reller 1972).

Beginning in late September, red-bellies, which have been rather strictly forest birds during the nesting season, expand their occupancy to other, more open, habitats. Whether this change is a movement of immatures, adults, or both is unknown. Nor is it known to what extent the ecological shift entails more than just local movement. At least a small part of the movement appears to be migratory. We have seen a few red-bellies flying with other diurnal migrants along the Mississippi and Ohio valleys on just three mornings between 30 September and 26 October (Fig. 18). The flight pattern and (appropriate southward) direction were the same as those of blue jays, red-heads, flickers, and other species that regularly migrate along these routes in fall. As we have never seen more than four red-bellies per hour on these routes, these migrations cannot account for a sizeable population shift by the species. A red-bellied woodpecker killed on a television tower near Meredosia, Illinois, and found with over 100 specimens of night migrants on the morning of 27 September 1972 (H. David Bohlen, personal communication) is the only indication we have of night migration by the species. Stoddard & Norris (1967) also reported a red-belly killed at a television tower (in Florida), but they did not believe the incident represented night migration.

In contrast to the spring populations of red-bellies, fall populations show pronounced peaks (Fig. 18), reflecting that the population is near its annual high and that the species is increasingly conspicuous as part of the population moves to more open habitats.

Our daily counts of birds in spring (March–May, inclusive) and fall (August–October) showed a ratio of 1.0 red-belly in spring to 2.1 in fall for the state as a whole, with very little difference in the ratios from region to region. There are no data on fall age ratios for the red-belly, as there are for the red-head, with which to interpret the spring-fall ratios. The fall-spring ratio for the red-belly is higher than that of any other woodpecker in Illinois.

Winter Populations

The distribution of winter records for the red-bellied woodpecker in Illinois is shown in Fig. 20. The species probably occurs in every county in winter, but published records are still lacking for several.

The fall dispersal of red-bellies that takes the birds into habitats not generally occupied in summer may also involve some extensive geographic displacement, i.e., more than the migration that has been observed. Kumlien & Hollister (1951) noted that in 1903 red-bellies appeared to be more common in winter than in summer near the northern edge of the species' range. Similarly, Beal (1911) in central Iowa found red-bellies "abundant" in winter every year, though he "never" saw one in the breeding season! We have noted the same same phenomenon—red-bellies apparently increasing disproportionately northward in winter. Alfred Gross made the cross-country censuses of 1907–1909, and we made them in 1957–1958, and in neither case were red-bellied woodpeckers detected within the northern Illinois census transects in summer. In winter, however, red-bellies came within the northern transects in both series of censuses (Tables 7 and 8). The density of the winter population of red-bellies increased greatly in the north between 1907 (1 bird per 100 acres in forest) and 1957–1958 (9.5 per 100 acres). The cumulative Christmas counts of red-bellies (Fig. 21) also show notable upward surges in northern Illinois, 1915–1925 and 1954–1959, and in central Illinois, 1919–1939 and 1954–1959, while the southern Illinois counts have remained relatively stable. Recent (1965–1975) annual variation in the Christmas counts has ranged from about 2 percent to 46 percent per year and averaged 20–21 percent in northern and southern Illinois but only 8 percent in the central region. On the long-term average, it took 3.6 party hours to find a red-belly on the northern Christmas counts, 1.2 hours on the central counts, and 1.0 hour on the southern counts.

The population dynamics of the red-bellied wood-

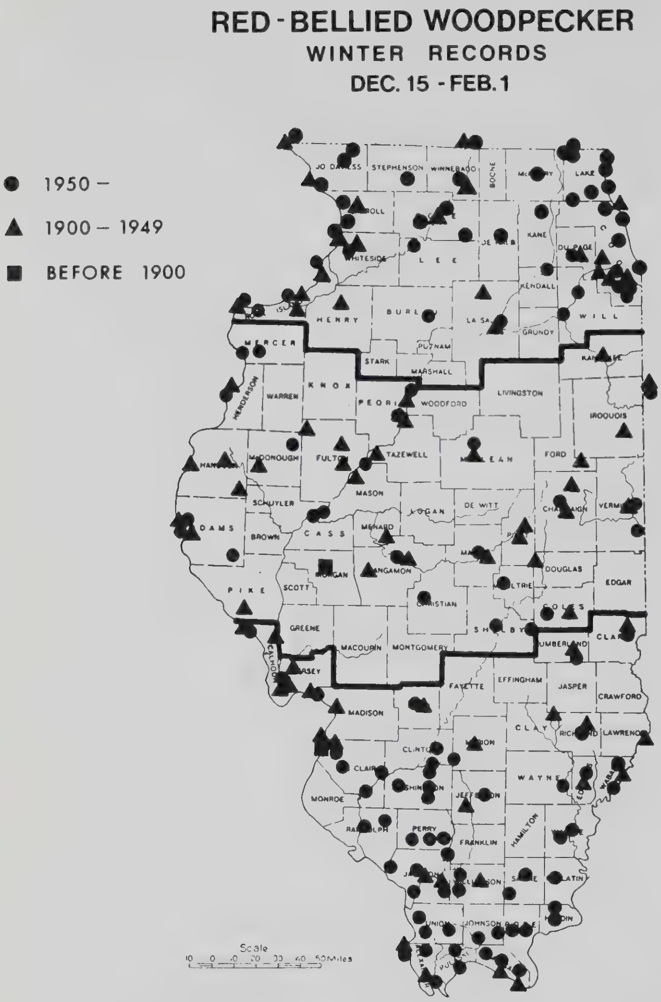


Fig. 20.—Distribution of winter records of the red-bellied woodpecker in Illinois. Heavy horizontal lines separate the three regions of the state (north, central, and south) referred to in the text.

pecker in Illinois are puzzling. From population density figures and habitat acreage figures, we estimated the June population of red-bellies in the state to be about 190,000 adult birds in 1957–1958, with about 150,000 in the southern region, 40,000 in the central region, and an almost negligible population (under 2,500) in northern Illinois. In winter (January) the state population jumped to about 515,000 (2.7 times the June number), with about 360,000 in southern Illinois (2.4 times the June number), 99,000 in central Illinois (2.5 times the June number), and an incredible 55,000 in northern Illinois (22.0 times the population of June). In more recent censuses in southern Illinois (1973–1975), the number of winter red-bellied woodpeckers was 2–3 times that found in summer in the same woodlands. To some extent the increase in winter reflects the increased conspicuousness of red-bellies in open field habitats and in forests with the foliage gone, but there is no reason to believe that conspicuousness is increased more in northern Illinois than in the other regions. The winter data for central and southern Illinois do not indicate any major exodus of red-bellies. Better population data are needed for both summer and winter populations, especially in the north, to answer at least these questions: (1) Is the great increase in numbers of red-bellies in winter real? (2) If so, why are the increases not comparable in central and northern Illinois? (3) Where does the excess winter population in the north come from?

Although the red-belly expands its occupancy of habitats in winter, forest remains an important habitat (Table 8). Winter population densities of red-bellies were higher in bottomland than in upland forest, as they were in summer (Tables 7 and 8). In southern Illinois Ferry (1907*a*) observed that red-bellies favored tall softwood trees of the river bottoms, where there was a large proportion of decayed tree trunks.

In five upland woods in southern Illinois in the winters of 1973–1975 we found positive correlations between the densities of red-belly populations and the Importance (Y) of hackberry, the Importance of ash, and high basal area, particularly of large trees. For hackberry the correlation was 0.906 ($P = < 0.02$); for ash, 0.969 ($P = < 0.01$); for total basal area, 0.866 ($P = < 0.05$); and for the ratio of the basal area of large trees to total basal area, 0.972 ($P = < 0.01$). There was a negative correlation between the numbers of red-bellied woodpeckers and the Importance of oaks ($r = -0.810$, $P = 0.05$) and of hickories ($r = -0.876$, $P = < 0.05$).

In eight bottomland woods in southern Illinois in the winter there was some correlation between red-

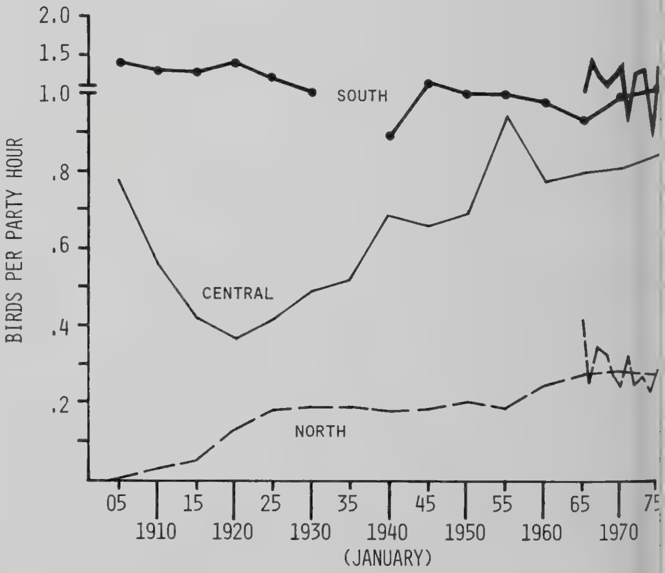


Fig. 21.—Red-bellied woodpeckers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average except that annual variation is shown between 1965 and 1975 for the north and south regions.

TABLE 8.—Winter populations of red-bellied woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Suburban woodlot	20	(+)[a]–10 (avg 5.0)	1968–1972	Map	Lake (N)[b]	Miller & Miller 1970, 1972
Urban residential	164	0.6	1976	Strip	North	This paper
Urban residential	191	0	1976	Strip	Central	This paper
Urban residential	191	5	1976	Strip	South	This paper
Oak-maple forest	55	0–16 (avg 5.5)	1925–1975	Map	Champaign (C)	Kendeigh 1944; Kendeigh et al. 1957
Oak-maple forest	55	0–4 (avg 1.5)	1925–1936	Map	Champaign (C)	Kendeigh 1944
Oak-maple forest	55	2–5 (avg 4.4)	1938–1949	Map	Champaign (C)	Kendeigh 1944, 1948*a*, 1949
Oak-maple forest	55	2–16 (avg 7.4)	1950–1975	Map	Champaign (C)	Kendeigh et al. 1951, 1957
Grazed bottomland woods	53	4–11 (avg 7.5)	1955, 1957	Map	Macon (C)	Chaniot & Kirby 1955*a*; Kirby & Chaniot 1957
Bottomland forest	50	(+)	1951	Map	Cook (N)	Montague 1951
Mature bottomland forest	1,398	0–25 (avg 9.6)	1974–1976	Strip	South	This paper
Mature upland forest	772	1–17 (avg 6.3)	1974–1976	Strip	South	This paper
Forest (all types, including edge)	46	4–9 (avg 6.5)	1940–1941	Map	Piatt (C)	Johnston 1942
Forest (all types, including edge)	65	1	1907	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	45	4–15 (avg 9.5)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	50	2	1907	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	152	4–10 (avg 7.9)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	241	5	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	7–12 (avg 9.5)	1957–1958	Strip	South	Graber & Graber 1963
Shrub habitat, including edge shrub	74	2–9 (avg 5.4)	1957–1958	Strip	Central	Graber & Graber 1963
Shrub habitat, including edge shrub	33	3	1907	Strip	South	Graber & Graber 1963
Shrub habitat, including edge shrub	101	15–18 (avg 16.8)	1957–1958	Strip	South	Graber & Graber 1963
Shrubby field and forest edge	85	(+)–1	1955–1956	Map	Richland (S)	Shaw & Stine 1955; Shaw et al. 1956
Shrubby field	40	(+)–10 (avg 4.4)	1958–1965, 1968	Map	Lawrence (S)	Scherer & Shaw 1960; Shaw et al. 1968
Pasture	440	0	1907	Strip	North	Graber & Graber 1963
Pasture	83	1	1957	Strip	North	Graber & Graber 1963
Pasture	343	2	1907	Strip	Central	Graber & Graber 1963
Pasture	156	0–2 (avg 1.3)	1957–1958	Strip	Central	Graber & Graber 1963
Pasture	208	1	1907	Strip	South	Graber & Graber 1963
Pasture	93	0	1957–1958	Strip	South	Graber & Graber 1963
Fallow fields	114	1	1907	Strip	South	Graber & Graber 1963
Fallow fields	103	2	1957–1958	Strip	South	Graber & Graber 1963
Cornfields	60	3	1907	Strip	South	Graber & Graber 1963
Cornfields	277	1	1957–1958	Strip	South	Graber & Graber 1963

[a] The plus symbol (+) indicates fewer than one bird per 100 acres.
[b] N refers to the northern region of Illinois, C to the central, and S to the southern region, as shown on winter distribution maps, e.g., Fig. 5.

bellied woodpecker numbers and the Importance of hackberry ($r = 0.730$, $P = < 0.05$). Likewise, there was some correlation between the density of red-bellied woodpeckers and the basal area ratio (basal area of large trees to total basal area) ($r = 0.701$, $P = < 0.05$). In the bottomland forest interior, red-bellies apparently seek the larger trees, especially maples and hackberries. The species can thus to some extent avoid the red-headed woodpecker, which predominates in the oaks in the bottoms. The presence of over 35 red-heads per 100 acres in bottomland woods seems to depress the red-bellied woodpecker population (Fig. 22). In four bottomland woods with over 35 red-heads per 100 acres, the red-bellied population was 3.5–5.5 birds per 100 acres. In four bottomland woods with red-headed woodpecker numbers of less than 35 per 100 acres, the red-bellied woodpecker population was 17.5–18 birds per 100 acres. In all

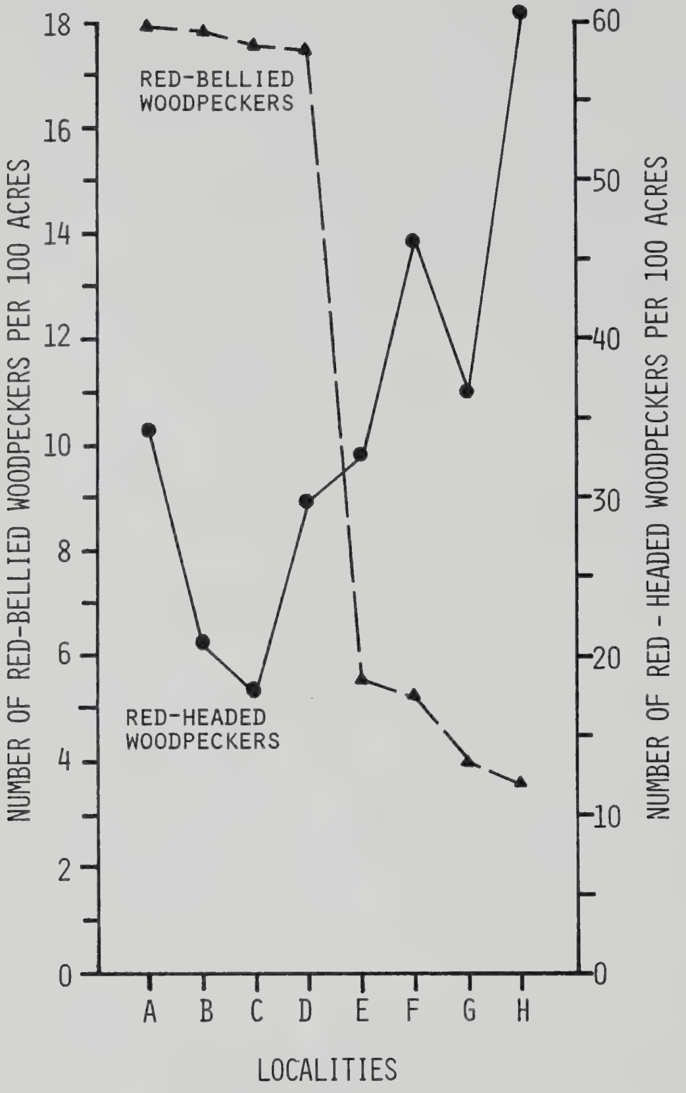


Fig. 22.—Inverse relationship between winter populations of red-headed and red-bellied woodpeckers. Points on the dash line represent numbers of red-bellied woodpeckers in eight bottomland woods in southern Illinois, identified in the introduction. Points on the solid line represent numbers of red-headed woodpeckers in the same woods.

eight woodlands there was a negative correlation ($r = -0.556$, $P = > 0.10$) between average populations of these two species for 3 years. In individual woodlands the negative correlation between these two populations in the 3 years was -0.781 ($P = > 0.10$); -0.843 ($P = > 0.10$); -0.916 ($P = < 0.10$); -0.987 ($P = < 0.02$); -1.00 ($P = < 0.001$). In two woodlands there was no correlation and in one there was a positive correlation (0.991, $P = < 0.01$). The very large old trees and the generic composition (many maples and hackberries) may have allowed this latter woodland to support high populations of both species (2-year average: 34 red-heads and 18 red-bellies per 100 acres).

Red-bellies are generally tree gleaners (Reller 1972), foraging on trunks and limbs of trees, and their presence in such open-field habitats as cornfields, fallow fields, and pastures in winter (Table 8) indicates some ground or near-the-ground foraging not mentioned in the Illinois literature.

Food Habits

Beal (1911), referring not specifically to Illinois, found the red-bellied woodpecker's food during the year to be about 31 percent animal matter and 69 percent vegetable. Of all food types, mast (acorns, beechnuts, hazelnuts, and pecans) was most important, constituting about 31 percent of all food and a much larger portion (67 percent in November) in fall and winter. We have seen red-bellies working on pecans in late September in the Mississippi Valley of Union County. Fruit, especially wild fruit, was also important throughout the year, but varied from a low in April (7.5 percent of the diet) to a high in August (64 percent).

Of animal food, beetles, most notably weevils and wood-boring species, were a consistent part of the diet, as were ants. Orthopterans—grasshoppers, crickets, and egg cases of cockroaches—were important throughout the year, though more so in summer.

There are few specific Illinois observations on the food. Ridgway (1889) believed the red-belly to be a pest in orchards because of its fondness for apples. Red-bellies eat corn, but not in economically significant amounts. Red-bellies have been observed feeding on chokecherries in southern Illinois (Ferry 1907*b*) and sassafras fruit in central Illinois (Allison 1947). The red-belly is also well known at feeders, taking suet, cheese, and grain, including sunflower seeds (Vredenburgh 1905; Schafer 1918; Cone 1956). Southern (1966) observed red-bellies feeding on dead gizzard shads in winter in northwestern Illinois.

Longevity

There are, to our knowledge, only two longevity records for the red-bellied woodpecker in Illinois, both around 5–6 years. A bird banded in 1966 south of McLeansboro, Illinois, was found dead 5 years and 8 months later in the same locality (computer printout from U.S. Fish and Wildlife Service Bird Banding Office 1972). Another bird banded in 1924 at Kansas, Illinois, was retrapped in the same place nearly 5 years later (Cooke 1937).

Specimen Data

Red-bellied woodpecker specimens from Illinois, of which we have examined 49 (28 males, 21 females), are for the most part separable from comparably plumaged specimens of the nominate race from South Carolina and Georgia, which have a darker appearance, especially on the back and rump. We consider all the Illinois specimens to represent *Centurus carolinus zebra* though there is great variation in back

TABLE 9.—Measurements of Illinois specimens of red-bellied woodpeckers, excluding obviously worn, molting, and juvenile specimens.

Region of Illinois	Months	Number of Specimens	Sex	Wing (Chord) in mm			Tail Length in mm			Culmen (from Naris) in mm		
				Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
North and Central	Dec.–Feb.	6	M	126–133	130.1	2.62	76–85	79.1	3.12	. . .	. . .	. . .
South	Dec.–Jan.	8	M	125–134	130.5	3.20	76–83	79.6	2.62	. . .	. . .	. . .
State	Mar–Apr. Oct.–Feb.	25	M	125–134	130.2	2.66	75–85	79.4	2.65	24–28[a]	25.8	1.11
State	Oct.–Mar.	20	F	121–134	127.5	3.05	75–86	78.5	3.54	23–25[a]	24.3	0.95

[a] Culmen measurements from only seven males and seven females.

color (black-to-white ratio), with about one-fourth of them showing coloration somewhat intermediate toward *C. c. carolinus.* There was no consistent color or size difference between specimens from northern and central Illinois and those from southern Illinois (Table 9). Females averaged slightly smaller than males in all measurements.

Weights of males from northern and central Illinois were 74.3 and 80.6 grams for April specimens, 83.6 for a February specimen, and 91.8 for a November specimen. Weights of female specimens from central Illinois were 78.6 grams (February specimen), and 73.9 and 74.2 grams (November specimens).

RED-HEADED WOODPECKER
(Melanerpes erythrocephalus)

(Fig. 23, 24, and 25)

Spring Migration

The impressive diurnal migrations of red-headed woodpeckers often seen in Illinois in fall have apparently never been recorded in spring. Most of the spring migration may be nocturnal. We have heard red-headed woodpeckers calling at night relatively rarely compared with the frequency with which we have heard the flicker. In east-central Illinois we have heard what we believed to be red-heads in migration on nights between 24 April and 7 May between 8:50 p.m. and 3:20 a.m. CST. Musselman's (1931) statement that red-heads "appeared over night" on 15 April 1930 also suggests night migration.

Because red-heads winter in some years in all parts of the state, the onset of spring migration is often obscured by the presence of wintering birds. Published spring arrival dates for the state range from mid-February (Beal 1886; Strode 1892; Gault 1901; Musselman 1932) to early May (Walter & Walter 1904). Red-head populations exhibit great annual variation in behavior, and this range of arrival dates is probably truly representative of the species, depending upon the year cited. The range of arrival dates is so variable that the spring migration of red-heads is not predictable with any accuracy in contrast to those of most migrant species.

The arrival dates most frequently cited in the Illinois literature fall in the period 23–30 April with no consistent difference between regions. There are also indications of migration waves in the periods 1–10 and 20–30 March and 5–15 April.

Our counts (Fig. 26) showed notable population changes in late March and early April in southern and central Illinois, and in late April and early May in central and northern Illinois. High spring populations came 7–23 April in southern Illinois, 29 April–7 May in central Illinois, and 9–13 May in northern Illinois (Fig. 26). Cooke (1943) reported on a bird banded in Highland Park on 20 May 1940, which was captured alive at Estelline, South Dakota, about 3 weeks later on 10 June—seemingly a very late migrant.

Distribution

The red-headed woodpecker is a species mainly of the eastern and central United States (Fig. 25). In Illinois red-heads probably nest in every county, though the breeding distribution is still incompletely known (Fig. 27).

Nesting Habitats and Populations

In the breeding season, the red-headed woodpecker is a savannah or forest-edge species with generally low populations in forests (Table 10, disregarding samples under 30 acres) unless the forests become opened up by some such calamity as fire, disease, or wind damage. Thus, Butler (1897) pointed out that red-head populations become very high at times of "deadenings," i.e., when trees are killed in epidemic proportions. Similarly, Yeager's (1949) study of flooded bottomlands showed that as flooding killed large numbers of trees, the woodpecker population—particularly the red-head population—surged upward. Musselman (1930) observed that red-heads were attracted to an area of fire-killed oaks. The relationships between red-head populations and dead trees is shown by the studies of Kendeigh and his students on Trelease Woods (Champaign County), where red-head numbers climbed dramatically as American elms (a dominant species) died from elm diseases on a mas-

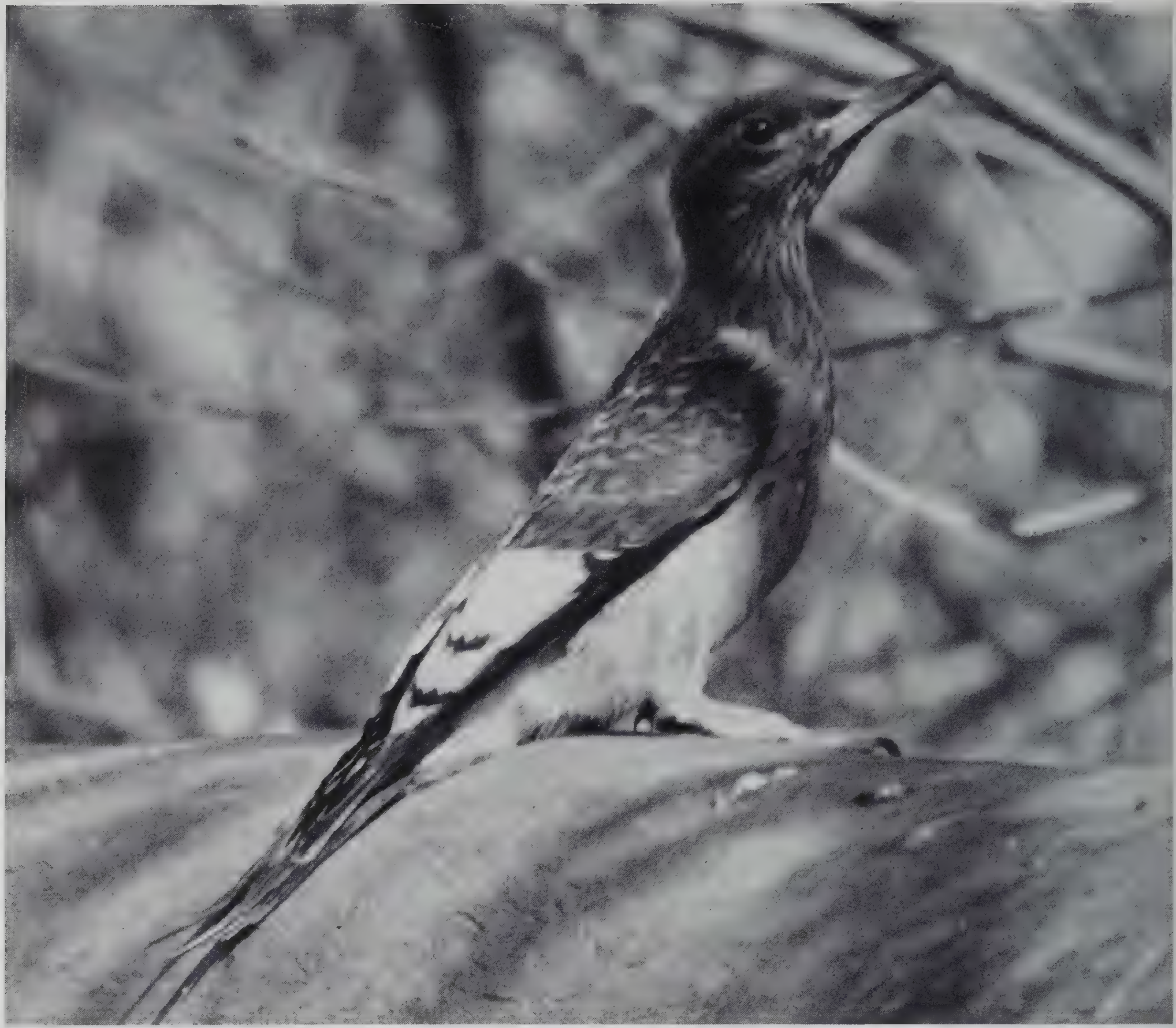


Fig. 23.—Juvenile red-headed woodpecker at Allerton Park, Piatt County, in October. A gray head and black bars on wings are characteristic of the juvenile plumage.

sive scale and opened up the forest (Kendeigh & Brewer 1956; Kendeigh & Brooks 1963*b*). Dutch elm disease, because of its wide distribution, has almost certainly been responsible for an increase in the state's red-head population in the past 20 years. As natural succession fills in the gaps where large elms fell, the red-head population is likely to decline again.

Red-heads nest in both upland and lowland habitats (Table 10). Our June censuses of 13 woodlands (5 upland, 8 bottomland) in southern Illinois indicate a strong preference by red-heads for bottomland woods in that region. In only one upland woods were any red-heads seen, and this particular upland woods adjoined a bottomland that had a high breeding population (over six birds per 100 acres).

Age of stand, basal area or density of all trees or any size class of trees, diversity, Importance of any species or genus (or any size class thereof) in the eight bottomland woods analyzed vegetatively could not be correlated with numbers of red-headed woodpeckers present in June. Five genera of trees (woody plants over 4 inches DBH) made up 75 percent of the Importance of trees in each of six woodlands having red-heads. These genera were *Quercus* (oaks), *Carya* (hickories), *Celtis* (hackberries), *Ulmus* (elms), and *Acer* (maples). One woodland (E) with a population of two to three birds per 100 acres consisted simply of 75 percent oak, 23 percent hickory, and the remainder ash, elm, and persimmon. The two bottomland woods without red-heads had less than 70 percent (Importance) of the five genera of trees mentioned above, and less than 45 percent of their compo-

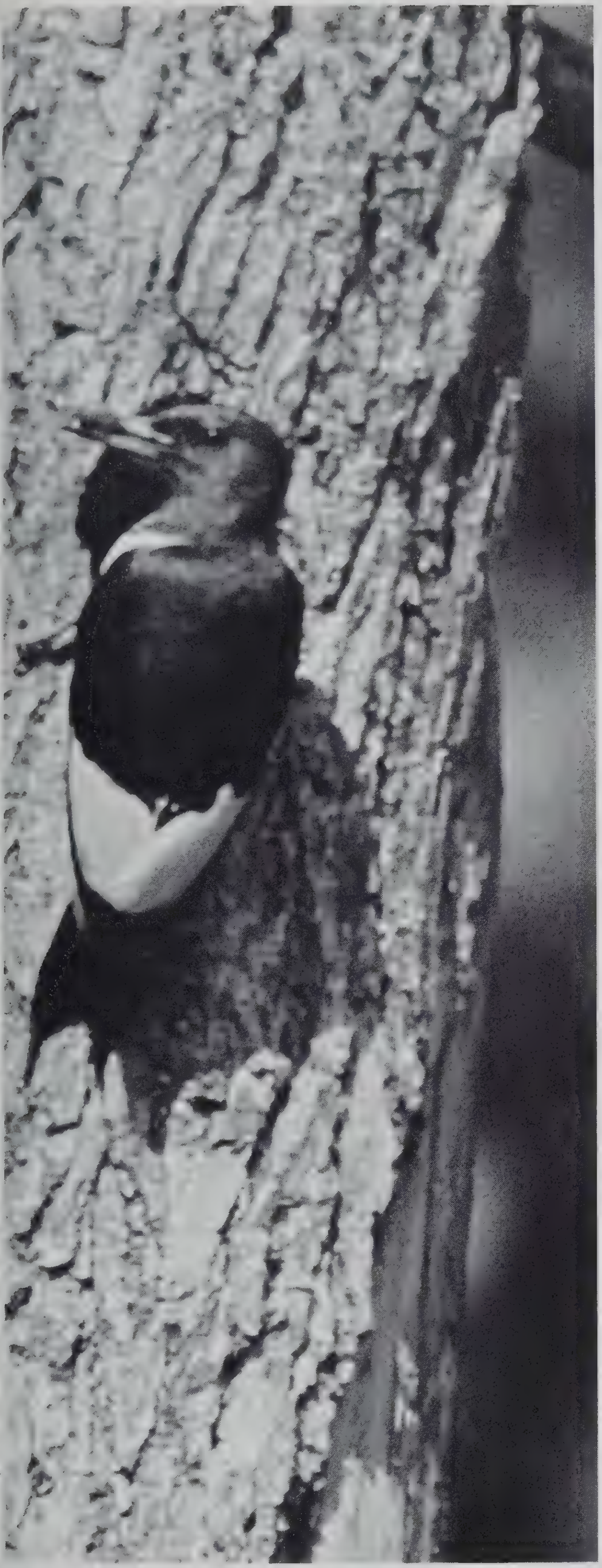


Fig. 24.—Adult red-headed woodpecker with food for its young at its nest hole 11 miles east of Havana, Mason County, Illinois, in early July.

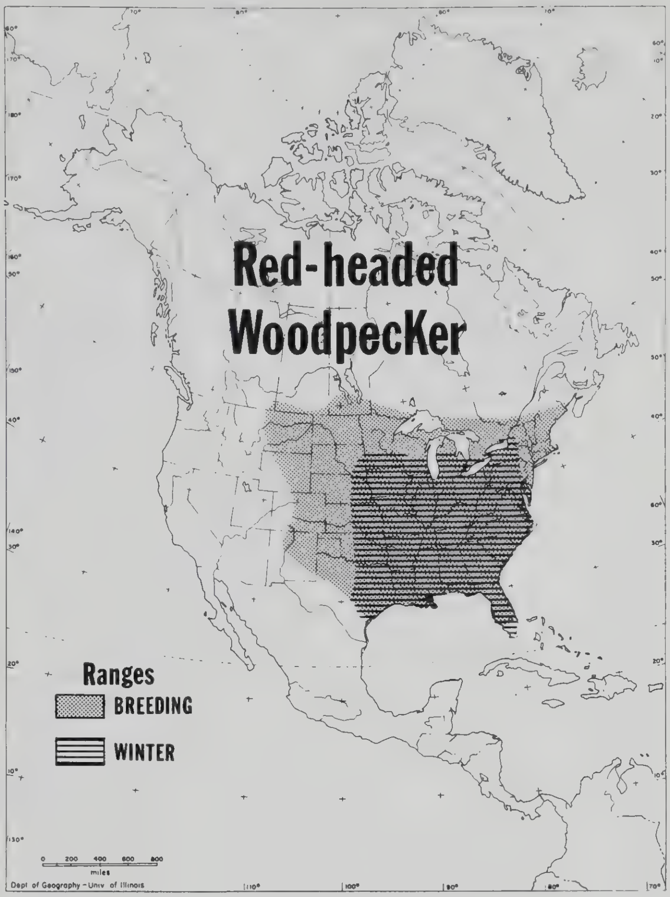


Fig. 25.—General distribution of the red-headed woodpecker. The range shown here may include large sections in which there are few, if any, red-headed woodpeckers because of the nature of the terrain and lack of suitable habitat.

sition was oak-hickory-hackberry-elm. The amount of forest edge and open areas within woods—providing in effect forest edge—are probably important to the red-head. In the eight bottomland woods studied, the highest populations (9–12 birds per 100 acres, 2-year average) occurred in woods that had a large amount of edge and internal openings either from fallen trees or because of the presence of streams and oxbows within them. The simple (in diversity) woodland (E) mentioned above had many irregular open areas within it because of a fire that had occurred some 10 years earlier. Williams (1975) found that red-headed woodpeckers in a central Illinois woodland spent most of their time foraging in oaks and dead trees in open areas in the woodland.

Red-headed woodpeckers are tolerant of humans. Ridgway (1887) considered the red-head by far the most numerous breeding woodpecker in the city of Mt. Carmel, and there are many old nest records for the species in cities throughout the state. More recently, however, urban populations of red-heads have been poor. The strip-censuses of 1957–1958 showed breeding populations of only two birds per 100 acres in southern Illinois towns (Table 10), while numbers

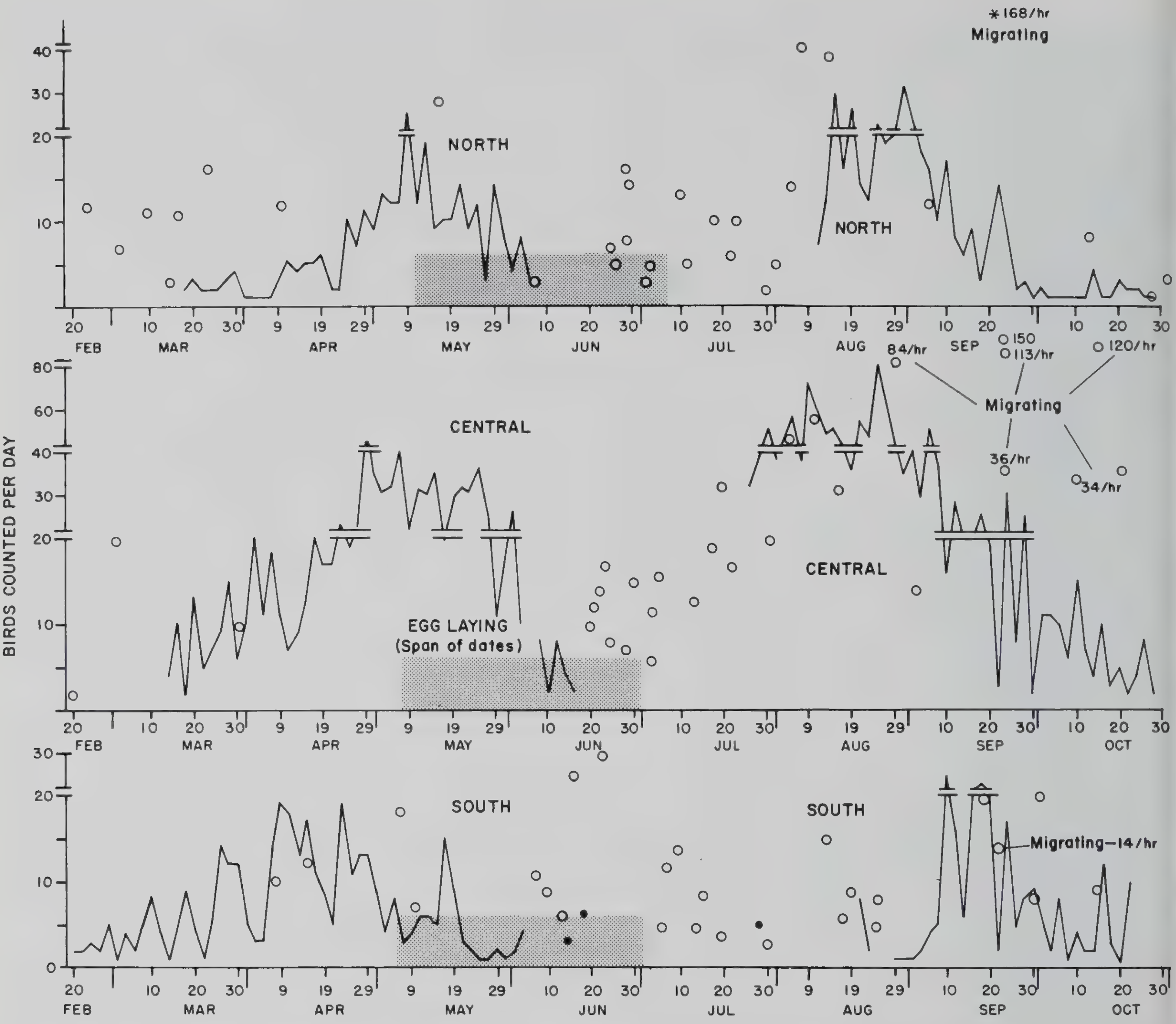


Fig. 26.—Egg-laying and migration seasons of the red-headed woodpecker in different regions of Illinois. Spring and fall graph lines show the higher daily count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Dark dots (southern region) represent isolated counts made in 1967. Shaded areas show the span of dates during which egg laying has been recorded.

in central and northern Illinois cities were too low to detect in our samples. In urban areas red-heads are in the starling's stronghold and often fail in competition with that species (Moseley 1947; Polder 1963).

As red-heads nest in shrub areas (Table 10) and other woody habitats more open than forest, the significance of dead trees to this bird may be primarily related to increased sunlight or visibility in the habitat. Nest sites of red-heads are often in dead trees. Published nest-site data for 47 red-head nests in northern and central Illinois showed about 80 percent to be in dead trees, usually in the trunks. Some of the nests reported in live trees may have been in dead branches. Of 33 nests for which we have data, 45 percent were in elms and 24 percent were in oaks.

From dead tree to utility pole would seem but a small change. W. S. Brenneman (personal communication) of the Illinois Power Company has studied woodpecker damage to utility poles and found the red-head to be the species by far most often involved in such damage.

Nest heights varied from 4 to 40 feet, with no significant mode, and averaged about 20 feet. In Champaign and Piatt counties, Reller (1972) noted that red-head nests faced predominantly south and west.

Reller (1972) also observed that in summer red-heads foraged to a large extent on the ground. The statewide strip censuses of 1907–1909 and 1957–1958 showed that red-heads were often found in grasslands

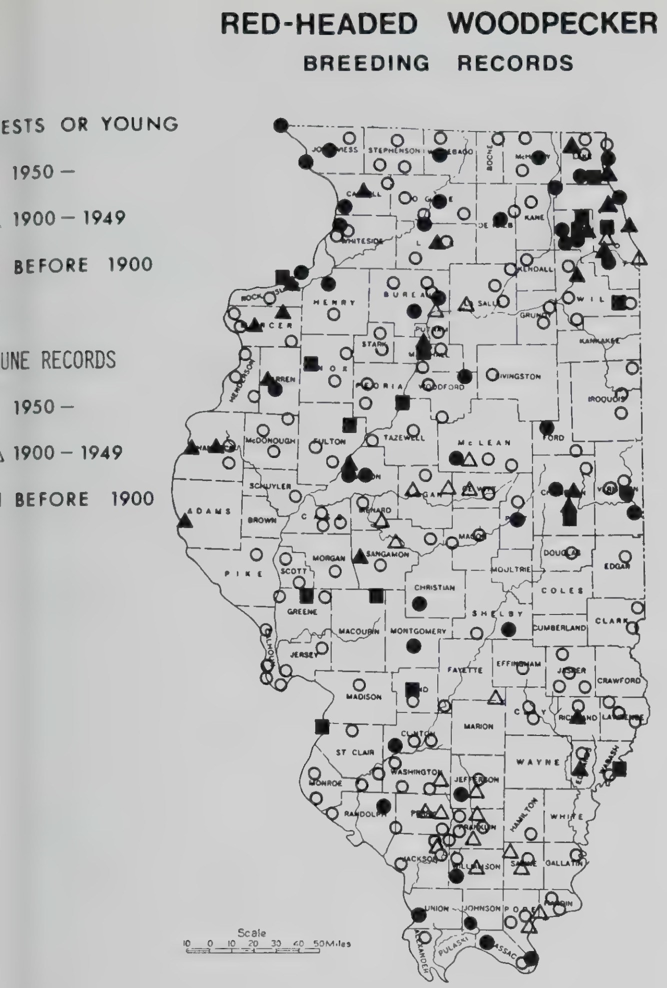


Fig. 27.—Distribution of breeding records of the red-headed woodpecker in Illinois. Hollow symbols represent birds seen or heard in June.

of all types in densities high enough (three to four per 100 acres) to indicate that this is an important foraging habitat for the species.

The population trend for the red-headed woodpecker since the turn of the century had been downward until recent years. We estimated the June population of breeding adults in Illinois to be about 1,270,000 in 1909 and only 115,000–134,000 in 1957–1958 (Graber & Graber 1963). Since then, coinciding with the great die-off of elms in the state's forests, red-head numbers have increased, but the level of the present state population is unknown. Our census figures for some southern forest areas (Table 10) provide an indication of the increase. In 1957–1958 red-heads were not detected in the forest transects, but in 1974 we recorded an average density of three birds per 100 acres in mature bottomland forest and of four birds per 100 acres in 1975.

The causes of the decline in the red-headed woodpecker population before the elm epidemic can only be surmised. White settlement of Illinois in the 18th and 19th centuries greatly reduced forest acreage but increased edge habitats that favored red-heads.

Since about 1920 habitats have changed increasingly to block forms while edge habitats have declined (Graber & Graber 1963). The two woodpecker species (red-head and flicker) that particularly occupied the edge underwent about the same decline (roughly 90 percent) between 1907 and 1957. A second factor that affected both species adversely in this period was the starling with its incredible population increase in the 20th century and its ability to compete with native species, particularly in managed habitats. The recent decline in the red-headed woodpecker's populations apparently ended when the elm epidemics created much new natural habitat. In recent years large reservoir construction has flooded extensive areas of lowland forest, killing the trees and creating more habitat for red-heads. The durability of this habitat is probably relatively short. Yeager's (1949) data show about one-fourth of the trees down in 8 years from the onset of flooding.

Eifrig (1937 and 1938) stated that red-head numbers were declining because of the automobile. He observed that red-heads were sometimes hit by cars as the birds picked up insects from the road. Red-heads do appear to show special susceptibility to this type of mortality (Flint 1926 and 1934–1935; Blocher 1927; Komarek & Wright 1929; Starrett 1938).

Few Illinois species seem as argumentative as the red-head. Much of the time they appear to be bickering among themselves or with other species. This intra- and interspecific aggression is exhibited both in and out of the breeding season (Cooke 1916; Schafer 1917; Ridgway 1920; Cone 1956; Willson 1970; Reller 1972). Hess (1910) suspected an inverse relationship between red-head and flicker populations in central Illinois, and in southern Illinois Bush (1934–1935) detected an inverse relationship between red-head and red-bellied woodpecker populations in winter. Reller (1972), Willson (1970), and Schafer (1917) observed that aggression was particularly keen between red-heads and red-bellied woodpeckers. Red-head strife has also extended to flickers, pileateds, downies, and other woodpeckers, starlings, brown creepers, house wrens, white-breasted nuthatches, blue jays, house sparrows, squirrels, and other species (E. E. 1885; Cooke 1885*b* and 1916; Butcher 1896; Field 1917; Moseley 1917; Ridgway 1920; Reller 1972; Moseley 1947). Red-heads also have a bad reputation for attacking other birds' nests, breaking and sometimes eating eggs (and even killing fledglings), mainly of cavity-nesters, e.g., chickadees, bluebirds, cliff swallows, and wood ducks, but also even of domestic chickens and of wood pewees (Willard 1896; Schafer 1920 and 1923; Frank Bellrose personal communication).

Nesting Cycle

A number of banding records indicate homing in Illinois red-head populations, and summer-banded

TABLE 10.—Breeding populations of red-headed woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Suburban residential	8	25	1916	Nest	Richland (S)[b]	Cooke 1916
Urban residential	235	0	1958	Strip	North & Central	Graber & Graber 1963
Urban residential	98	2	1958	Strip	South	Graber & Graber 1963
Modified woodland (human housing)	28	14	1937	Nest	Lake (N)	Beecher 1942
Unmodified woodland	27	15	1937	Nest	Lake (N)	Beecher 1942
Oak-maple forest	55	0–18 (avg 6.0)	1927–1943	Map	Champaign (C)	Kendeigh 1944
Oak-maple forest	64	3	1947	Map	Champaign (C)	Johnston 1947
Oak-maple forest edge	1.25 miles[c]	0–46 (avg 13.7)[c]	1944–1975	Map	Champaign (C)	Kendeigh 1948*b*; Kendeigh & Brooks 1965*b*
Forest (all types, including edge)	177	1–6 (avg 4.0)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	214	3–6 (avg 4.7)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	60	5–13 (avg 10.0)	1907, 1909	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	340	0	1957–1958	Strip	South	Graber & Graber 1963
Grazed bottomland woods	53	4	1955	Map	Macon (C)	Chaniot & Kirby 1955*b*
Mature bottomland forest	1,077	0–18 (avg 3.4)	1973–1975	Strip	South	This paper
Mature upland forest	479	0–1 (avg 0.4)	1974–1975	Strip	South	This paper
Upland second-growth oak-hickory	56	4–11 (avg 5.9)	1941–1942, 1944	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*, 1944*b*
Second-growth hardwoods	15	27	1937–1938	Map	Rock Island (N)	Fawks 1937, 1938
Woods (unspecified)	20	10–20 (avg 16.7)	1914–1916	Nest	Rock Island (N)	J. J. Schafer (unpublished notes 1914–1923)
Woods (unspecified)	54	7–23 (avg 16.3)	1917–1923	Nest	Rock Island (N)	J. J. Schafer (unpublished notes 1914–1923)
Savannah	23	18	1957–1958	Strip	North & Central	This paper
Orchard	45	4–5 (avg 4.4)	1907, 1909	Strip	South	Graber & Graber 1963
Orchard	78	0	1957–1958	Strip	South	Graber & Graber 1963
Late shrub	21	10	1966	Map	Vermilion (C)	Karr 1968
Shrub area	50	3–7 (avg 4.0)	1957–1958	Strip	Central	Graber & Graber 1963
Shrub area	56	28	1907, 1909	Strip	South	Graber & Graber 1963
Shrub area	129	0	1957–1958	Strip	South	Graber & Graber 1963
Swampy prairie	64–67	9–19 (avg 14.3)	1941–1942, 1944	Map	Sangamon (C)	Robertson 1941*a*, 1942*a*, 1944*a*
Pasture	193	3	1909	Strip	North	Graber & Graber 1963
Pasture	279	0–1 (avg 0.4)	1957–1958	Strip	North	Graber & Graber 1963
Pasture	441	4–7 (avg 5.9)	1907, 1909	Strip	Central	Graber & Graber 1963
Pasture	171	0	1957–1958	Strip	Central	Graber & Graber 1963
Pasture	882	2–4 (avg 2.6)	1907, 1909	Strip	South	Graber & Graber 1963
Pasture	120	0	1957–1958	Strip	South	Graber & Graber 1963

[a] All figures were converted to birds per 100 acres (territorial males or nests × 2).
[b] S refers to the southern region of Illinois, C to the central, and N to the northern region, as shown on the winter distribution maps, e.g., Fig. 5.
[c] These entries are miles of forest edge and birds per mile of edge.

birds—presumably local breeders—have returned as early as 17 April (Lincoln 1927).

Little has been recorded on the red-head's nesting cycle in Illinois, and virtually nothing on its nesting in the southern region. In northern Illinois Gault (unpublished notes 1889) observed nest excavation in progress on 25 April, and in central Illinois Musselman (1937) observed mating of red-heads on 5 May.

As is typical of woodpeckers, no nest is constructed, and the white eggs are merely laid on the floor of the cavity, often on wood chips from the excavation. Polder (1963) observed the excavation of a nest cavity in 2 days by a pair of red-heads. Sizes of natural cavities used as red-head nests have not been measured in Illinois. Ford (1939) gave these nest-box dimensions for this species: floor, 6 × 6 inches; depth, 12–15 inches; height of entrance above floor, 9–12 inches; diameter of hole, 2 inches. Gault (unpublished notes 1877) measured one cavity that was 9 inches deep. Red-heads have used nest boxes in Illinois, and Musselman (1934 and 1935) recorded about a 5 percent frequency of occupation of bluebird boxes by red-heads. Frank Bellrose and Robert Crompton (personal communication) have never found red-headed woodpeckers nesting in wood duck boxes though flickers commonly do so.

Egg laying begins at least as early as 6 May in southern Illinois, 7 May in central Illinois, and 11 May in northern Illinois, and occurs at least as late as 7 July in the north (Fig. 26). Laying, especially in the south, probably begins earlier than present records show. Data on clutch sizes are mainly from old literature or old museum records. The average of 30 clutches from northern and central Illinois was 4.7 eggs, with the frequency distribution being: 6 eggs, 21 percent; 5 eggs, 43 percent; 4 eggs, 27 percent; and 3 eggs, 10 percent.

Neither the incubation period nor the duration of nestling life have been measured in any Illinois population of red-heads. Observations by Kyler (1927) indicate that nestling life may exceed 3 weeks, but it has not been precisely measured.

There are no measurements of nesting success for any Illinois population of red-heads. The earliest we have seen young out of the nest was 18 June in the south and 7 July in central Illinois, where fledglings are frequently observed in the 2nd week of July.

Red-headed woodpeckers sometimes raise two broods. Reller (1972) observed that at least 3 pairs, of 15 under observation in central Illinois, nested a second time while still caring for the first broods fledged.

Age Ratios

The distinctive and relatively long-lived juvenile plumage of the red-headed woodpecker (Fig. 23) provides a potentially useful indicator of productivity in this species. Kyler (1927) hand reared three young red-heads and found that red began to appear on their heads about 10 weeks after hatching. During our censuses, when we were able to see red-heads clearly enough to age them, we recorded adults and juveniles, or immatures, separately. The ratios of the two age groups are shown in Table 11. As the first birds fledged in June and July, the proportion of young was naturally low—only 8 percent by 20 July in west-central Illinois. There was a consistent, progressive increase in the percentage of young from summer into fall (Table 11). We observed a ratio of 0.9 young per adult among red-heads migrating along the Mississippi River in a large migration of these birds on 21 September.

Note also (Table 11) that while the percentage of young increases later in the season, the total number of birds seen declines, suggesting that adults tend to precede the young in migration. Nelson (1876–1877) believed that it was young birds which tended to winter in Illinois. We have often seen immatures, with dark or partly dark heads and juvenile wing patterns, in January, but we have seen only one bird with that combination of characters as late as 9 April. Immatures with partly red heads are seen commonly in early September.

Fall Migration

The diurnal migration of red-headed woodpeckers in Illinois is sometimes conspicuous, with 100 or more birds passing a given point in an hour. The birds fly silently, singly, and in loose, somewhat linear groups, generally fewer than 20 birds at a time with 5- to 15-minute gaps between groups. They fly at heights ranging from 50 to 600 feet or more above local terrain. The birds follow essentially the same flight line, passing over or parallel to distinctive topographic features, most notably the scarp of a floodplain. Often up to 15 or more other species are involved in these flights, most often blue jays, whose numbers generally far exceed the numbers of red-heads and other species. Though the migration routes of the red-head and jay do coincide in places, it is not known whether the routes are the same throughout the state. We have seen both species migrating along the Mississippi, Illinois, and Ohio rivers. We have not witnessed such migrations on other waterways, and there are no published observations of the migration elsewhere in the state though it is to be expected on other major streams and perhaps along the Lake Michigan shore. The directions of

Table 11.—Age ratios of red-headed woodpeckers in central Illinois (1969) and northern Illinois (1968).

Date	West-Central		East-Central		Northwestern	
	Total Birds Aged	Percent Immature	Total Birds Aged	Percent Immature	Total Birds Aged	Percent Immature
July 11–20	65	8	...	..	...	..
July 21–31	172	30	...	..	...	..
August 1–14	168	54	187	25	...	..
August 15–31	119	50	193	40	202	24
September 1–30	54	61	171	44	150	47
October 1–31	5	..	53	57	8	..
Total	*583*		*604*		*360*	
Mean (after July)		54		38		33

the fall flights are generally downstream, south or west of south, but eastward (Widmann 1907) and southeastward (Cooke 1888) flights have been observed at St. Louis. Weber (1966) witnessed an apparent reverse (northward) fall migration up the Mississippi at Keokuk. We have seen red-heads migrating under both clear and cloudy skies, including overcast, and with southerly and northerly winds and in calms. The relationship (if any) of these flights to frontal weather systems is unknown.

The highest flight density we have recorded was 168 red-heads per hour on 21 September 1968 near Thomson, Illinois, on the Mississippi, but Widmann (1907) counted 284 per hour crossing the Mississippi at St. Louis on 15 September 1884. More frequently we have observed densities of 80–120 red-heads per hour in September and October on the Mississippi and Illinois rivers (Fig. 26). The highest flight density we have seen on the Ohio River was only 14 red-heads per hour. Our observations have all been made from the Illinois side of the rivers. Such migrations occur on both sides as well as over the Mississippi River, but there are no data on where the river migrants originate their flights and little on their seasonal, annual, or geographic variation. We have usually seen the flights between 6:00 and 11:00 a.m. CST, but the large flight seen by Weber was mostly in the afternoon (11:30–4:30 p.m.). These migrations are heaviest in September and October. They begin at least by 28 August (Graber 1962; Nolan 1957*a*) and extend to at least 26 October.

Such migrations occur every year, but not every day of the season. Many days in September and October we have looked for the flights in vain. Although such migrations are impressive, they do not seem to account for even a large part of the massive population shift of red-heads that occurs every year between summer and winter at Illinois latitudes. We have observed what appeared to be long-distance daytime flights of single red-heads across country where there was no obvious association with distinctive topography. The headings were southeast in east-central Illinois and southwest in west-central Illinois. Such flights may merely represent the origins of the flights along the rivers where the birds become concentrated.

Besides these diurnal flights, red-heads also migrate at night, but the relative volume of diurnal versus nocturnal migration is unknown. Ridgway's (1881*a*) father heard red-heads migrating at night over Wabash County in early October 1879. Nearly all of the local population vanished concomitantly with that migration. We have also heard what we believed to be red-heads calling at night, apparently in migration in east-central Illinois on a few nights between 7 September and 22 October between the hours of 8:00 p.m. and 4:00 a.m. CST. The presence of red-heads among the night migrants killed at television towers in Illinois 9–29 September is also indicative of night migration, but the species is relatively rare as a tower casualty—only 5 red-heads among over 12,000 birds identified from tower kills in Illinois.

The ratio between the numbers of birds counted in spring and those counted in fall is particularly interesting for the red-headed woodpecker because of the age-ratio data we have for this species. If the spring population is the adult breeding population and the fall population is the surviving adult population plus the surviving young, then we may expect some consistent relationship between the age ratios and the spring-fall ratios. In northwestern Illinois we saw 1.5 red-heads in fall (August–October, inclusive) for every one seen in spring (March–May, inclusive). As the age ratio for that region was 0.5 young per adult, the fall numbers were about as expected. In east-central Illinois the spring-fall ratio was 1.0:1.6, and the age ratio was 0.6 young per adult, thus in line with the fall ratio. In west-central Illinois, where the age ratio was the highest—1.2 young per adult—the fall ratio was lowest, 1.0 in spring to 1.2 in fall. We cannot explain the discrepancy. In the south the spring-fall ratio was 1.0:1.1; our age-ratio data in the south were too scanty to evaluate.

Winter Populations

Red-headed woodpeckers have been found in all regions of the state in winter (Fig. 28), but such a statement tends to obscure the fact that massive changes occur every year in the red-head population between summer and winter. Fall migration shifts the population southward, generally leaving few birds in the northern region and much reduced numbers in the central region, whereas the population in southern Illinois may be greatly increased over the summer level. Mast production of oaks, beeches, and other food plants have a pronounced effect on the regular migrations of red-heads in fall and winter, and variation in the winter population is extreme. In some winters red-heads remain even in the north in large numbers (Schafer 1922; Fig. 29).

There is some evidence that the winter populations of red-heads have been extending their range northward. The great annual variation in winter populations makes this difficult to prove, but several observations, including the Christmas counts, suggest it. During his life time, Holland (1931) saw a definite increase in the winter population at the latitude of Knox County. Dr. S. C. Kendeigh's censuses of Trelease Woods in Champaign County also show a trend toward an increased winter population there. The extensive cross-country censuses of Alfred Gross and Howard Ray in the winter of 1906–1907 revealed no red-heads in the central region of the state although red-heads were found on both of our (1957 and 1958) cross-country winter censuses (Graber & Graber 1963). If there is a progressive change in

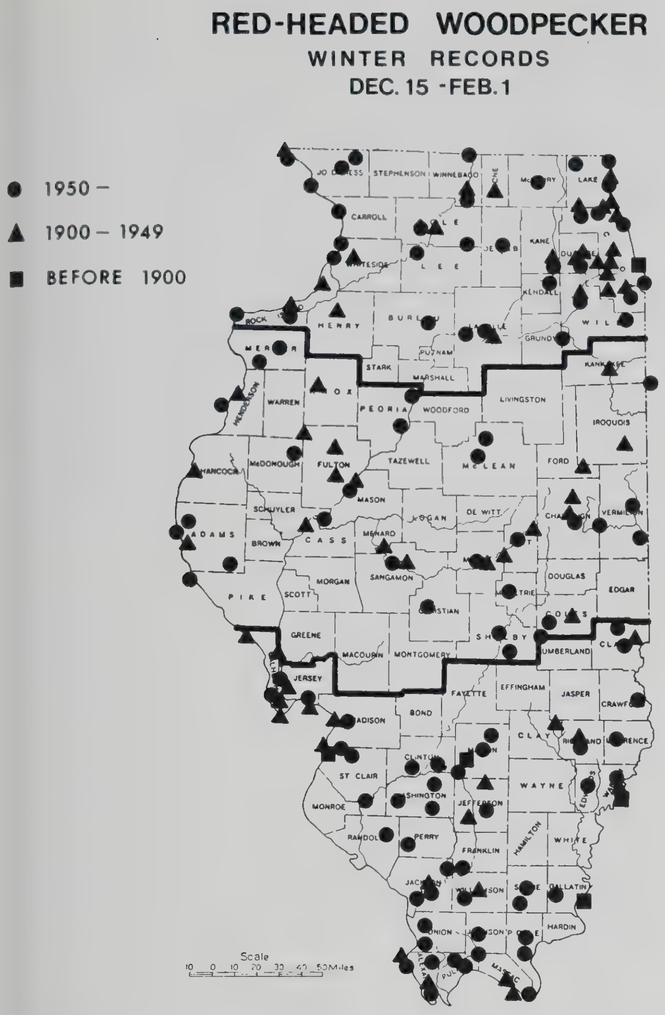


Fig. 28.—Distribution of winter records of the red-headed woodpecker in Illinois. Heavy horizontal lines separate the three regions (north, central, and south) referred to in the text.

range, it is very erratic, with notable regressions some years (Fig. 29).

As in summer, red-headed woodpecker populations in southern Illinois were censused in eight bottomland and five upland forests in the winters of 1973–1976. When all of the bottomland woods were considered, no significant correlations were found. However, when the two woods having the highest winter populations and the two woods having the lowest winter populations were examined, a few correlations were found. There was a positive correlation between the number of red-heads and oaks of acorn-bearing size, over 10 inches DBH ($r = 0.909$, $P = < 0.05$ for 1975 and $r = 0.961$, $P = < 0.01$ for 1976). These same four woodlands also showed a correlation between number of red-heads and the Importance of pin oak ($r = 0.839$, $P = < 0.10$ in 1975 and $r = 0.930$, $P = < 0.05$ in 1976).

Holland (1931) observed that the same oak woods were chosen for winter resorts by red-heads year after year in Knox County. Other observers (Musselman 1930; Mooney 1932; Willson 1970) have called attention to the red-head's affinity for oaks (and acorns) in winter. Willson (1970) and Reller (1972) suggest that maples also are important in the winter habitat.

In uplands the only wintering red-heads not found in woods adjoining bottomland woods were in a tract which had very heavy beech mast. In the following 2 years there was little or no beech mast in this woods, and no red-heads were found there. The average number of winter red-heads in bottomland woods (35 per 100 acres) was about four times the number (9 per 100 acres) in upland woods for the same 3-year period. There is an indication of an alternate high-low population fluctuation in our data. In 1973–1974 there were 20 red-heads per 100 acres (in all woods, upland and bottomland); in 1974–1975 there were 31 red-heads per 100 acres; in 1975–1976, 21 per 100 acres; and 58 per 100 acres in 1976–1977. This pattern of high red-head populations in the odd-numeral years is in agreement with the observations of Anderson (1965 and 1967), who noted the alternate-year cycle in Missouri, where the population was relatively low in (January) 1964, high in 1965, low again in 1966. The alternate-year pattern does not appear with any constancy in the Christmas counts. In the central region there are several-year runs of alternate high and low counts, but more often in the south there are 2, or sometimes 3, relatively high years followed by a drop (Fig. 29). We have found no statistically significant correlation between the annual counts in different regions of the state. The 5-year averages of the Chirstmas counts for the three regions of the state suggest an inverse relationship between winter populations of red-heads in southern versus central and/or

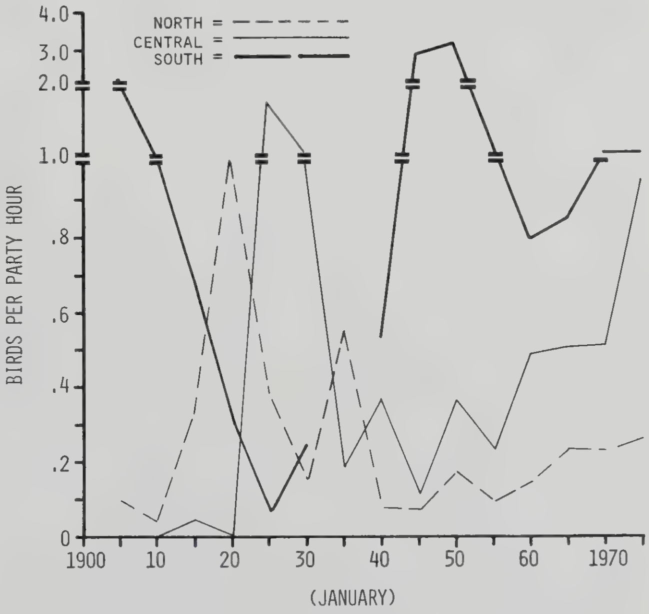


Fig. 29.—Red-headed woodpeckers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average.

northern Illinois (Fig. 29). Annual variation in Christmas counts in recent years (1965–1975) for the red-head ranged from about 3 to 160 percent per year (excluding one change of 555 percent in the north, 1974–1975) and averaged about 45 percent per year in southern Illinois, 57 percent in central Illinois, and 43 percent in the north.

The statewide censuses of 1957–1958 show how varied the winter populations may be (see also Table 12). In the winter of 1956–1957 we estimated the state population of red-heads to be 92,000 (72 percent in the southern region), but the next winter the state population was 424,000 (98 percent in the south). This population appears to be an exception to the odd-year highs of the 1960's and 1970's mentioned above. The sources of these winter birds in Illinois are unknown.

Besides the great population shift to the south in winter, red-heads move from the more open forest edge and savannah habitats to forest proper almost exclusively. This change may be less a change in the bird than a change in the habitat, i.e., an opening of the forest from the loss of foliage, the forest thus becoming a well-lighted, more open habitat similar to that which the red-head occupies in summer. However, Reller (1972) observed a definite change in foraging by red-heads from ground foraging in summer to tree trunk and limb foraging in winter.

Food Habits

There are numerous brief observations on the food habits of the red-headed woodpecker in Illinois, but there are no comprehensive studies on the subject. Rice (1946) examined six specimens from Champaign County, and found that vegetable matter made up 70 percent of the food in winter, 45–50 percent in spring and fall, but was absent from the diet in summer, when insects, especially Lepidoptera and Coleoptera, comprised most of the food. Coleoptera were important in the diet (15–20 percent of the food) at all seasons, and Hymenoptera (25 percent) were especially important in fall, less so (10 percent) in summer. Forbes' (1882*a* and 1882*b*) study of four specimens taken in late May at a Tazewell County orchard heavily infested with canker worms showed that 80 percent of the red-heads' food was insects, mainly (64 percent) Coleoptera (ground beetles and scarabs) plus 15 percent Lepidoptera (canker worms), and 20 percent vegetable matter (corn). Red-heads commonly forage by "flycatching," but what they catch has not been recorded.

Among all the Illinois references to mast consumption by red-heads, little specific data are provided. Musselman (personal communication, 1962) and Smith & DuMont (1945*b*) have called attention to the importance of pin oak fruit in the fall and winter diet of red-heads in the Mississippi valley. Musselman also mentions red oaks as being attractive to red-heads (Mumford 1959*a*), and we have often seen them working on white oak acorns. However, the relative values to red-heads of the various species of acorns have not been studied. Also not yet studied is the red-head's use of acorns versus beechnuts or other mast.

Red-heads have been seen storing acorns in their

TABLE 12.—Winter populations of the red-headed woodpecker in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Urban residential	355	0	1976	Strip	North & Central	This paper
Urban residential	191	0–1 (avg 0.5)	1976	Strip	South	This paper
Oak-maple forest	55	0–42 (avg 12.5)	1954–1962	Map	Champaign (C) [a]	Kendeigh 1960*a*; Kendeigh & Brooks 1962
Oak-maple forest edge	1.25 miles[b]	0–23[b] (avg 6.8)	1963–1975	Map	Champaign (C)	Kendeigh & Brooks 1964*a*; Kendeigh & Clemans 1970
Forest (all types, including edge)	46	0–6 (avg 3.3)	1940–1941	Map	Piatt (C)	Johnston 1942
Forest (all types, including edge)	152	1–3 (avg 2.0)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	241	1	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	2–15 (avg 8.1)	1957–1958	Strip	South	Graber & Graber 1963
Mature upland forest	772	0–33 (avg 8.2)	1974–1976	Strip	South	This paper
Mature bottomland forest	1,398	4–89 (avg 33.7)	1974–1976	Strip	South	This paper
Grazed bottomland forest	53	0–4 (avg 1.3)	1955–1957	Map	Macon (C)	Chaniot & Kirby 1955*a*, 1956; Kirby & Chaniot 1957
Shrubby field	40	0–7	1958–1965, 1968	Map	Lawrence (S)	Scherer et al. 1959; Shaw et al. 1968

[a] C refers to the central region of Illinois and S to the southern region, as shown on winter distribution maps, e.g., Fig. 5.

[b] These entries are miles of forest edge and birds per mile of edge.

own nest cavities (Jones 1933) and under the bark and in crevices of trees (Sanborn 1921). Moseley (1917) witnessed similar storage of suet, which may be used to attract these woodpeckers (Brintnall 1918; Williams 1924) although Schafer (1918) found cracked walnuts a more effective attractant. In South Dakota Winkenwerder (1902) reported red-heads storing live grasshoppers in tree crevices. The only reference on the amount of food materials stored is an anonymous (1922) observation of a red-head that worked throughout the winter at Moline, putting about 400 acorns and pieces of oak bark into two wren houses. The cache, which was never used, weighed 12¾ ounces at the end of the winter.

Formerly, at least, red-heads were sometimes considered pests on cultivated fruit, notably strawberries, cherries, pears, and apples (Gault, unpublished notes 1895; Le Baron 1855; Kinney 1868). Lyon (1923) found apples to be a good bait for trapping red-heads, and they also feed on mulberries in season. Southern (1966) observed one feeding on a dead gizzard shad in winter.

Beal's (1911) study of the red-headed woodpecker's food in North America showed the species to be much more of a vegetarian than most woodpeckers—animal matter constituting about 34 percent of the diet and vegetable matter 66 percent. Beetles, including most notably large adult predaceous ground beetles (Carabidae) and tiger beetles (Cicindelidae), made up about 19 percent of the food. The red-head was also less of a wood driller than other woodpeckers, taking few wood-boring larvae. Ants comprised about 5 percent of the year's food, going as high as 14 percent in June and July. Red-heads ate large numbers of grasshoppers in August (21 percent of the diet), and less in September (9 percent). Also in August and September grain, notably corn, became a significant part (22 and 19 percent, respectively) of the red-head's diet. Small fruits (blackberries, cherries, etc.) averaged about 3 percent of the year's food, going as high as 17 percent in July. Especially from October to January, mast (mainly acorns) became the predominant food, averaging about 55 percent of the diet.

Mortality and Longevity

In addition to the losses due to automobiles, mentioned earlier in this paper, red-heads are also lost because of pesticides. Montgomery (1956) found one dead after DDT was sprayed on trees to control Dutch elm disease, and a nest failed when both adults succumed to a tree spray (Mumford 1961). Red-heads were 3 of 259 prey items in screech owl boxes (Brown & Bellrose 1943).

There are few published Illinois records of longevity and none of more than 2 years (Lincoln 1927; Cooke 1937). Subfossil remains of red-headed woodpeckers were found at the Modoc Rock Shelter and were aged 3,000–8,000 B.C. (Parmalee 1959).

LEWIS' WOODPECKER *(Asyndesmus lewis)*

There are two sight records of Lewis' woodpecker for the state, one on 24 May and 26 May 1923 in Roger's Park (Evanston) on the north side of Chicago (Hine 1924) and one on 14 May 1932 at Argo (Summit) on the south side of Chicago (Ford 1956).

YELLOW-BELLIED SAPSUCKER *(Sphyrapicus varius)*

(Fig. 30 and 31)

Spring Migration

Yellow-bellied sapsuckers may be found in all parts of Illinois in winter, but the spring migration becomes conspicuous as the numbers of sapsuckers increase in March and April (Fig. 32). The migration has apparentely never been witnessed directly in spring, and may be strictly, or at least largely, nocturnal (see under Fall Migration). A large kill of 141 sapsuckers in or along the beaches of Lake Michigan on the night of 16 April 1960 may have occurred while the birds were in night migration (Segal 1960). A similar incident involving only two sapsuckers near Waukegan on 2 May was reported by Boulton & Pitelka (1937).

February records refer most often to the winter population, but apparent migration waves may be detected as early as 21 February, particularly in southern Illinois. More typically the first waves are noted after 15 March, with noticeable influxes occurring between 21 and 31 March (Oberholser 1928; Smith 1930). Musselman (1932) recorded one large influx on 14 March at Quincy. Peak numbers of sapsuckers come even later, in early and mid-April, and most of them have passed north of Illinois by the end of April (Fig. 32). In some years, particularly in east-central and northeastern Illinois, large numbers of transient sapsuckers appear. Beal (1886) recorded such an invasion on 9 April 1886, the birds remaining for 3 days. Except for such invasions, sapsuckers are usually seen singly or in twos, and generally one sees not more than five per day.

In southern Illinois very few sapsuckers linger past April, the latest date on record being 5 May (Oberholser 1928; George 1968). In central and northern Illinois, where a very thin and spotty breeding population survives, a few sapsuckers stay on through the summer, but nearly all sapsuckers seen in Illinois are transients, which pass through central and northern Illinois by mid-May (Fig. 32).

Benjamin Gault's unpublished records from 1875 to 1927 in northeastern Illinois indicate that males tend to predominate in numbers in the early spring migration through the first week in April after which

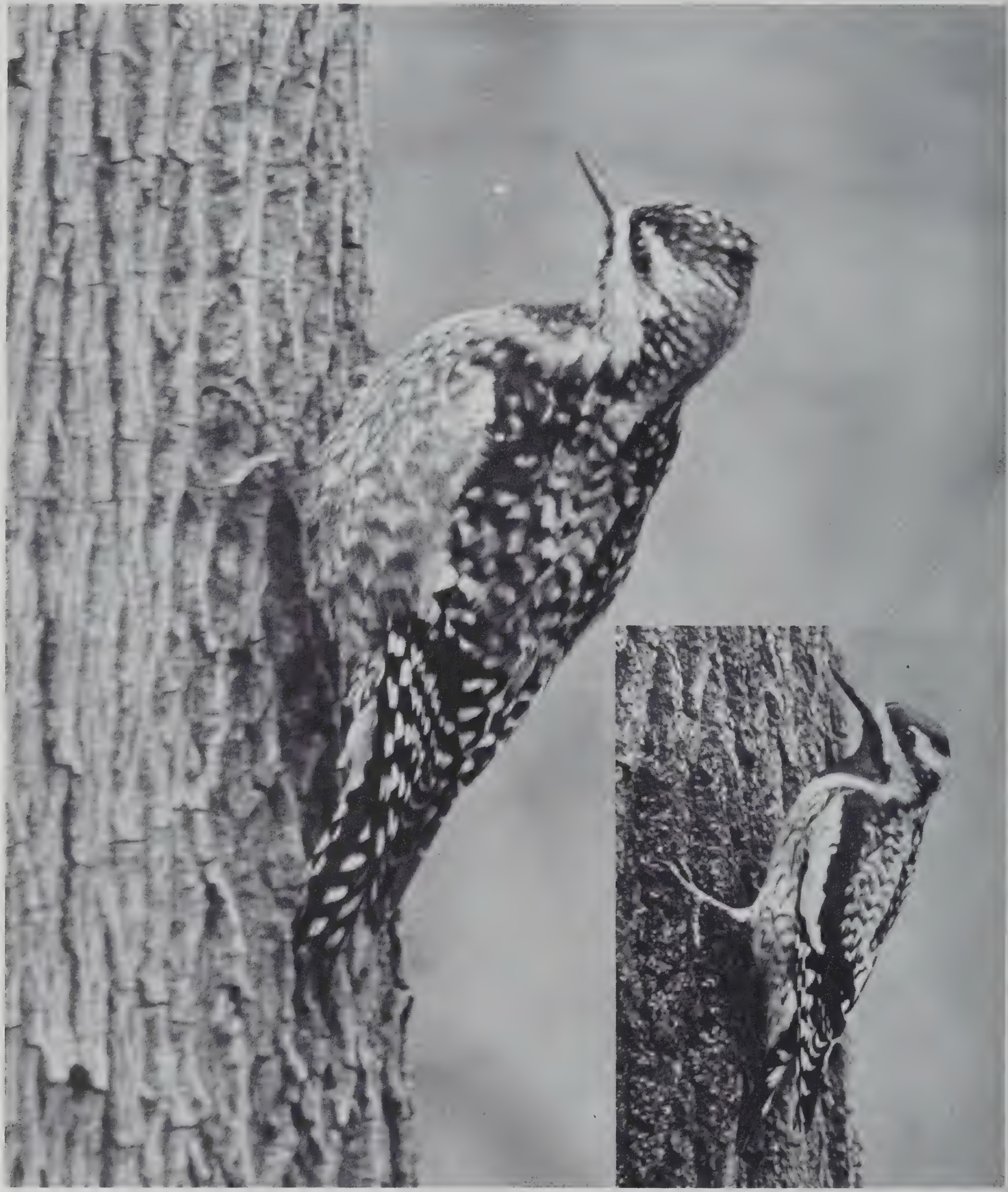


Fig. 30.—Immature yellow-bellied sapsucker. Photo taken by J. W. Graber in Busey Woods (Urbana, Illinois) in April. Inset shows adult yellow-bellied sapsucker. Photo by Dr. W. J. Beecher, Chicago Academy of Sciences.

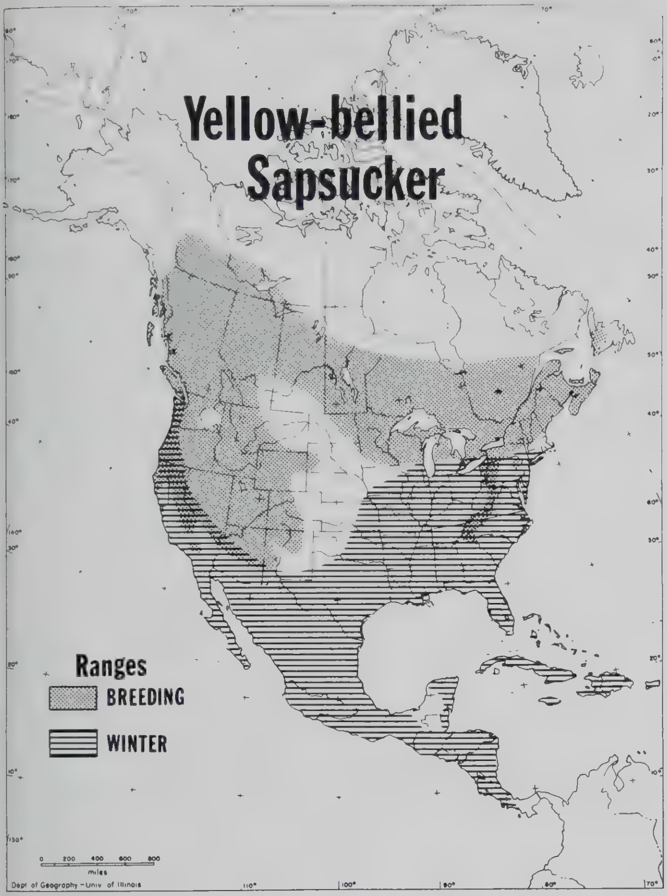


Fig. 31.—General distribution of the yellow-bellied sapsucker. The range shown here may include large sections in which populations of the species are thin or absent because of the nature of the terrain and lack of suitable habitat.

females become more common and predominate in the later migrations after 20 April. The transients show a broad tolerance for woody habitats, occurring in urban areas as well as in extensive forests. Actual measurements of transient populations of sapsuckers are lacking for any habitat.

Distribution

In eastern North America the yellow-bellied sapsucker nests in the northern USA and Canada, but the breeding range extends well south in the western USA as well as in the mountains of the east (Fig. 31).

In Illinois the breeding range is very spotty (Fig. 33) and probably now restricted to northern and central Illinois though suitable looking habitat is plentiful in southern Illinois. The old record for St. Louis (Fig. 33) is that of Hurter (1884). The fact that neither Ridgway (1889) in southeastern Illinois nor Widmann (1907) in the St. Louis area knew the sapsucker as a breeding species in their respective areas implies that the species was not a common nester in the south even in the last century. The significance of a sight record for a sapsucker at Horseshoe Lake (Alexander County), 13 August 1932 (Gower 1933) is uncertain.

Nesting Habitats and Populations

No breeding population of sapsuckers has been measured systematically in Illinois. Petersen's (1956) discovery of three active nests in Henderson County in 1 day (19 June 1955) and DuMont's (1936) reference to the species on the Des Moines River across the Mississippi from Illinois indicate that there are measurable populations in or near the Mississippi valley. In the Illinois valley Loucks (1891) considered the species rare at Peoria, but a short distance to the north, in Marshall County, Barnes (1890) called it "tolerably common."

The preferred nesting habitat is lowland forest subject to flooding (Barnes 1890; DuMont 1936; Petersen 1956). There is also an indication of sapsuckers nesting in urban residential habitat (Roberts 1922).

No territories have been measured in any habitat.

Nesting Cycle

Nesting of the sapsucker has not been studied in Illinois. Near Peoria Silloway (unpublished manuscript 1923) observed what he called nuptial activities of sapsuckers (possibly transients) on 6 April, noting that the birds were very noisy. The call most often heard in Illinois is a distinctive catlike squeal.

Nest cavities in Henderson County were 30–45 feet high in living oaks (Petersen 1956). In Marshall County R. M. Barnes found nests in both dead and live willows, the nest height varying from 12 to 20 feet (Chicago Museum of Natural History oological collection). Loucks (unpublished manuscript 1891) describes a nest 15 feet up in a dead tree in Tazewell County.

Old literature and museum records indicate that egg laying by sapsuckers in northern Illinois extends from at least 20 April to 3 June (see also Bent 1939). The same sources indicated that clutch size varies usually from four to six eggs. Barnes considered the clutch of eight eggs that he found near Lacon to be very exceptional (Chicago Museum of Natural History oological collection).

There are no data on nesting success in Illinois.

Fall Migration

Aside from the very slim breeding population, sapsuckers do not appear in Illinois again until September. Benjamin Gault's long-term records show that sapsuckers are rarely seen before 10 September even in northern Illinois (see Schafer 1923; Blake & Smith 1941 for early records). They increase conspicuously in northern and central Illinois between 15 and 24 September, and most of them have passed through the north by 12 October and through central Illinois by 20 October (Fig. 32). Our earliest fall record for the

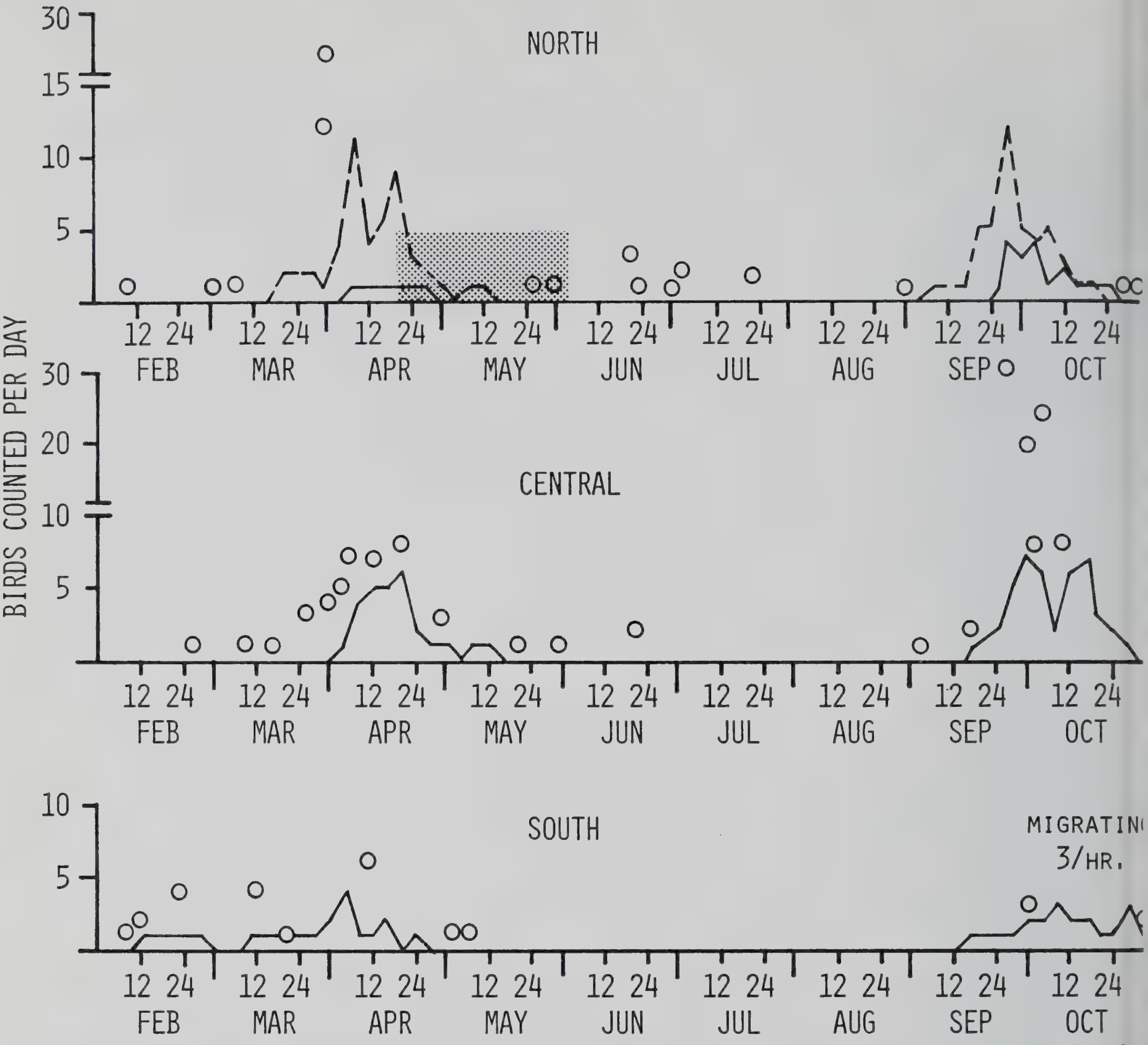


Fig. 32.—Egg-laying and migration seasons of the yellow-bellied sapsucker in different regions of Illinois. Spring and fall graph lines show the higher daily count of each 4 days (1967–1970). The dashed graph line (north) represents the cumulative counts of sapsuckers made by Benjamin T. Gault between 1875 and 1927, mainly in Du Page County. Hollow circles represent counts made in other years or by other observers. The shaded area (north only) shows the span of dates during which egg laying has been recorded.

south was 17 September. Because the migrant population of sapsuckers in the south appears low (Fig. 32) and the winter population there is relatively high, the end of the fall migration in the south is obscured. Peak numbers of transient sapsuckers have been seen 20 September–8 October in northern Illinois, 28 September–18 October in central Illinois, and 8–28 October in southern Illinois. Balch (1970) observed a large wave of sapsuckers at Waukegan 22 September 1970.

The data on bird kills at television towers in central Illinois also show the migration pattern of sapsuckers there. The kill data span August–November 1955–1972, during which period about 12,000 dead birds (all species) were picked up and identified. All (43) of the sapsuckers were killed between 23 September and 7 October (Brewer & Ellis 1958; Petersen 1959), a period in which sapsuckers constituted about 1 percent of all (4,400) birds killed. Nearly all of these sapsucker specimens, adults and immatures, were still clearly in the molt on the head and anterior body. Graber's (1968) view that few sapsuckers are killed compared with the number seen is yet to be verified.

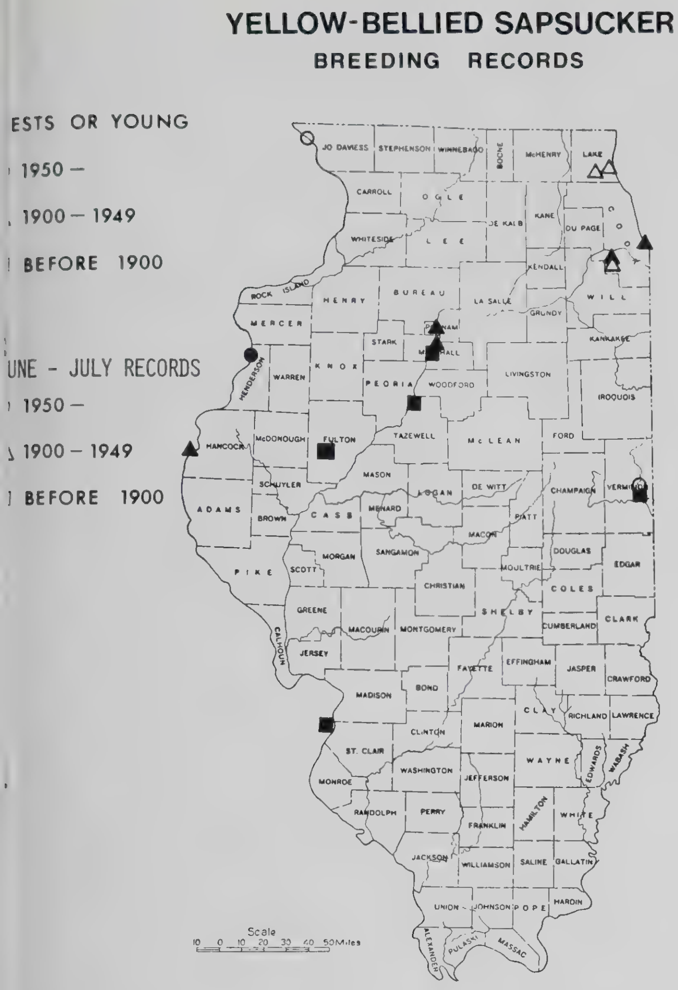


Fig. 33.—Distribution of breeding records of the yellow-bellied sapsucker in Illinois.

Most of the migration must be nocturnal. Besides the evidence of the tower kills, we have heard what we believed to be sapsuckers uttering the characteristic cat call while migrating at night (8:20 p.m.–5:20 a.m.) over east-central Illinois between 12 September and 14 October. We have seen diurnal migration of sapsuckers but once—1 October 1972 (morning), the birds flying with jays and other woodpeckers down the Ohio valley in Pope County.

Our counts showed a ratio of 1.0 sapsucker in spring to 1.8 in fall statewide, but there was a progressive decline in the ratio from north (1.0 to 2.9) to central (1.0 to 1.9) to south (1.0 to 1.3). The age ratio in a small sample (22) of specimens from a central Illinois tower kill was 1.0 adult to 1.75 immatures.

Winter Populations

Yellow-bellied sapsuckers have been found in all regions of the state in winter (Fig. 34), but the population declines progressively from south to north, as the Christmas count data clearly show (Fig. 35). The occurrence of sapsuckers in the north in winter is irregular (Duncan 1937), in some years falling virtually to zero (Fig. 35), but annual variation is great in all regions. The long-term averages of Christmas count data show that it has taken about 92 party hours of observation to find a sapsucker in the north, versus 45 hours in central Illinois, and 17 in the south.

Judging from population densities, we conclude that bottomland forest and residential areas are the favorite winter habitats. The highest population we have measured in a tract at least 40 acres in size was about 12 sapsuckers per 100 acres in a mature bottomland forest in Alexander County in January 1975, a year with notably high populations in the south (Fig. 35). Average populations were 1.6 sapsuckers per 100 acres in both mature bottomland and urban residential habitat in the south, but only 0.4 per 100 acres in mature upland oak-hickory. Shrub habitat is also used in the south (Shaw 1961; Table 13).

Prior to about 1939 the Christmas counts had too few knowledgeable participants in Illinois to detect sapsuckers with any regularity The record since then

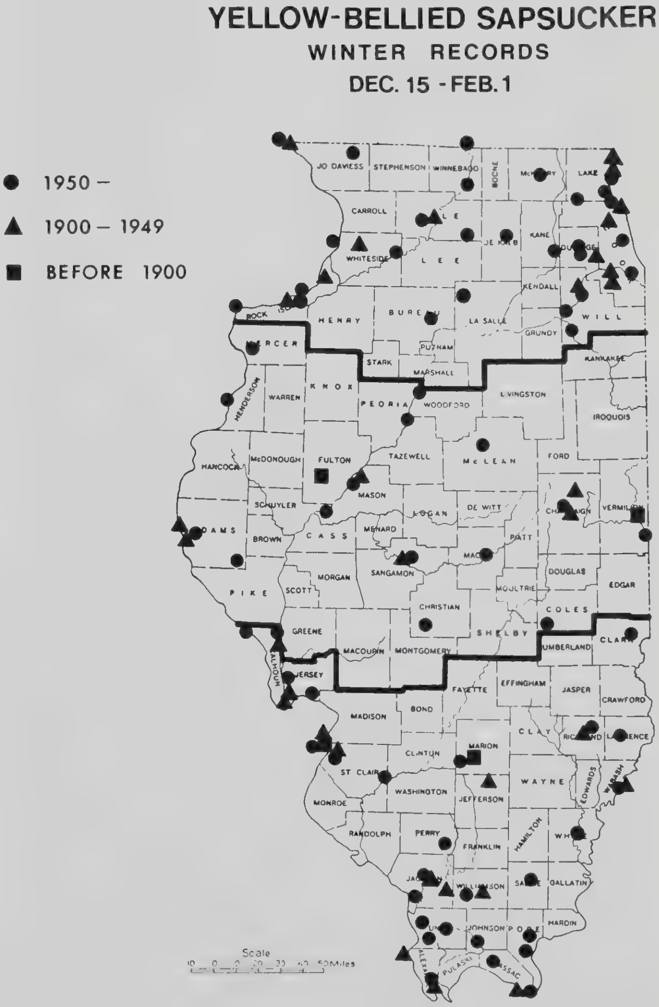


Fig. 34.—Distribution of winter records of the yellow-bellied sapsucker in Illinois. Heavy horizontal lines separate the three regions (north, central, and south) referred to in the text.

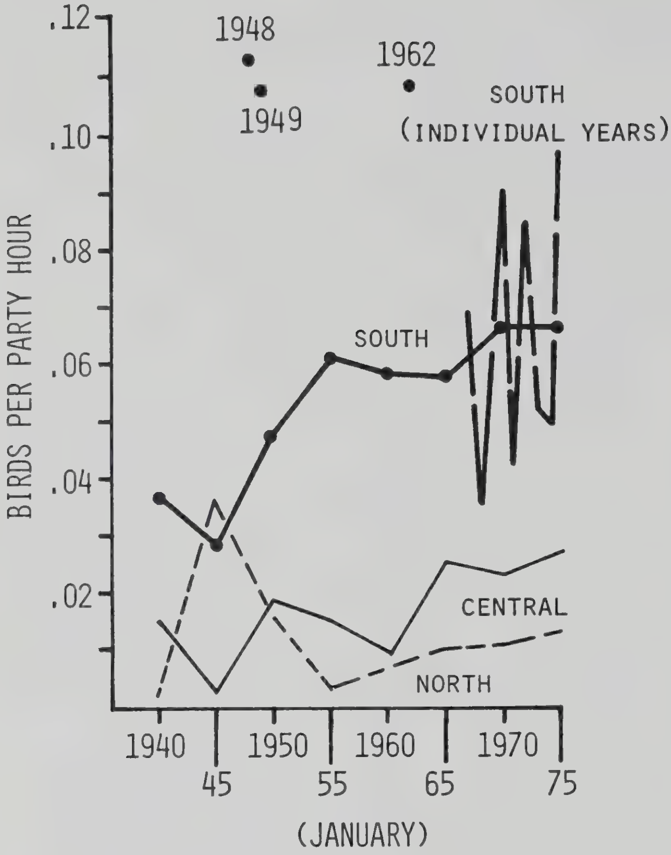


Fig. 35.—Yellow-bellied sapsuckers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average. The dash line shows annual fluctuations in the southern Illinois counts in recent years. Dots designate high counts in 1948, 1949, and 1962.

shows an upward trend in winter numbers in more recent years (Fig. 35) though the highest count was in the southern region in January 1948, a high also noted by Cunningham (1948). The southern counts for 1949 and 1962 were also exceptionally high (Fig. 35). Extreme annual variation in the counts makes any conclusion tenuous, particularly as the aggressiveness of Christmas count participants in finding birds has also been increasing over the years. The counts show some tendency toward alternate year highs and lows (Fig. 35), but the pattern is far from consistent. The early cross-country censuses of Alfred Gross and Howard Ray, conducted in southern Illinois in February 1907 may also indicate that the sapsucker winter population is increasing. They detected no sapsuckers in 241 acres of forest, whereas we found an average of about two sapsuckers per 100 acres in 1957–1958 (Table 13). However, there is now no way we can determine whether 1907 was a "low" year for sapsuckers.

Sapsuckers were about four times as numerous in bottomland woods as in upland woods in southern Illinois. They prefer larger trees ($r = 0.924$, $P = < 0.001$ between numbers of trees over 22 inches DBH and numbers of sapsuckers). The sapsucker population proportionately increased in woods with greater numbers of large trees (Fig. 36). There was also a negative correlation ($r = -0.804$, $P = < 0.01$) between sapsucker numbers and the percentage of the total basal area of a forest made up of small trees, 4–10 inches DBH.

The composition of bottomland woodlands favored by wintering sapsuckers reflected their food preferences. Maples usually constitute more than 15 percent in Importance (Y), elms more than 10 percent, and oaks less than 25 percent. There were positive correlations between the numbers of sapsuckers and the Importance of pecan ($r = 0.617$, $P = < 0.10$); pecan and sugar maple (the latter not very numerous in bottomland) ($r = 0.820$, $P = < 0.01$); pecan, sugar maple, and tulip tree ($r = 0.733$, $P = < 0.05$); and elms ($r = 0.604$, $P = < 0.10$). There was a negative correlation for the Importance of oaks ($r = -0.601$, $P = < 0.10$). Sapsuckers seldom drill the species of oaks that are dominants in these woodlands. The sapsucker apparently shares the winter habitat of the red-bellied woodpecker and downy woodpecker, as its numbers correlate with numbers of those species ($r = 0.736$ and 0.742, respectively, $P = < 0.05$).

Table 13.—Winter populations of the yellow-bellied sapsucker in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Urban residential	164	0.6	1976	Strip	North	This paper
Urban residential	191	1.6	1976	Strip	South	This paper
Suburban woodlot	20	0–(+) [a]	1968–1972	Map	Lake (N) [b]	Miller & Miller 1968
Forest (all types, including edge)	241	0	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	1–4 (avg 2.4)	1957–1958	Strip	South	Graber & Graber 1963
Mature bottomland forest	1,398	0–12 (avg 1.6)	1974–1976	Strip	South	This paper
Mature upland forest	772	0–6 (avg 0.4)	1974–1976	Strip	South	This paper
Shrubby field	40	0–2	1958–1965, 1968	Map	Lawrence (S)	Shaw 1958, 1961

[a] The plus symbol (+) indicates fewer than one bird per 100 acres.
[b] N refers to the northern region of Illinois and S to the southern region, as shown on winter distribution maps, e.g., Fig. 5.

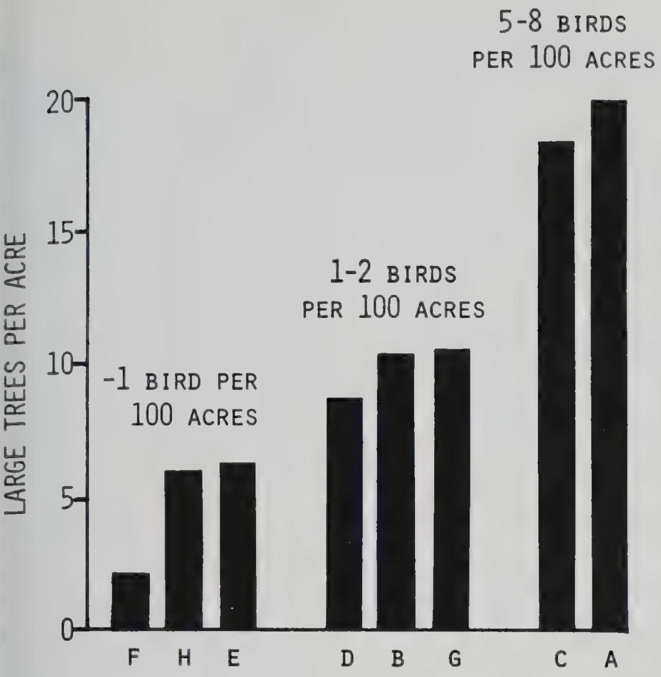


Fig. 36.—Relationship of yellow-bellied sapsuckers to large trees (trees over 22 inches DBH). Bars represent eight different bottomland woods in southern Illinois.

The upland woods in which wintering sapsuckers were found in southern Illinois were adjacent to bottomland woods and had more maples (mostly sugar maples) than had upland woods in which no sapsuckers were found (the Importance of maples was greater than 9 percent in upland woods with sapsuckers present).

Food Habits

Though there are a number of references to the presence of sapsuckers at winter feeding stations (Beall 1908; Smith & DuMont 1945*b*; Fawks 1966 and 1970), few tell what food was taken by the species. Musselman (1933) mentions sapsuckers eating suet. Sapsuckers have also been observed feeding on the fruit of hawthorn (*Crataegus* sp.), "matrimony vine" (DuMont 1947*a*), and "winterberry" (Link 1940).

Most of the Illinois literature on the food of sapsuckers concerns tree drilling (Fig. 37). Though other woodpeckers feed to some extent on cambium and sap, the sapsucker clearly lives up to its name when it comes to this method of foraging. Beal (1911) found that the sapsucker's food through the year was about 49 percent animal, and 51 percent vegetable, making it the only woodpecker he studied that eats more vegetable than animal matter. Ants were apparently the favorite animal food, constituting about 34 percent of the diet and being taken throughout the year but most commonly from May to August. Various beetles were also important in the diet, making up about 5 percent of the food.

The common types of vegetable food for sapsuckers were fruit (28 percent of the diet) and cambium (16.5 percent). The fruit, notably a variety of wild berries, was taken mainly in fall (71 percent of the

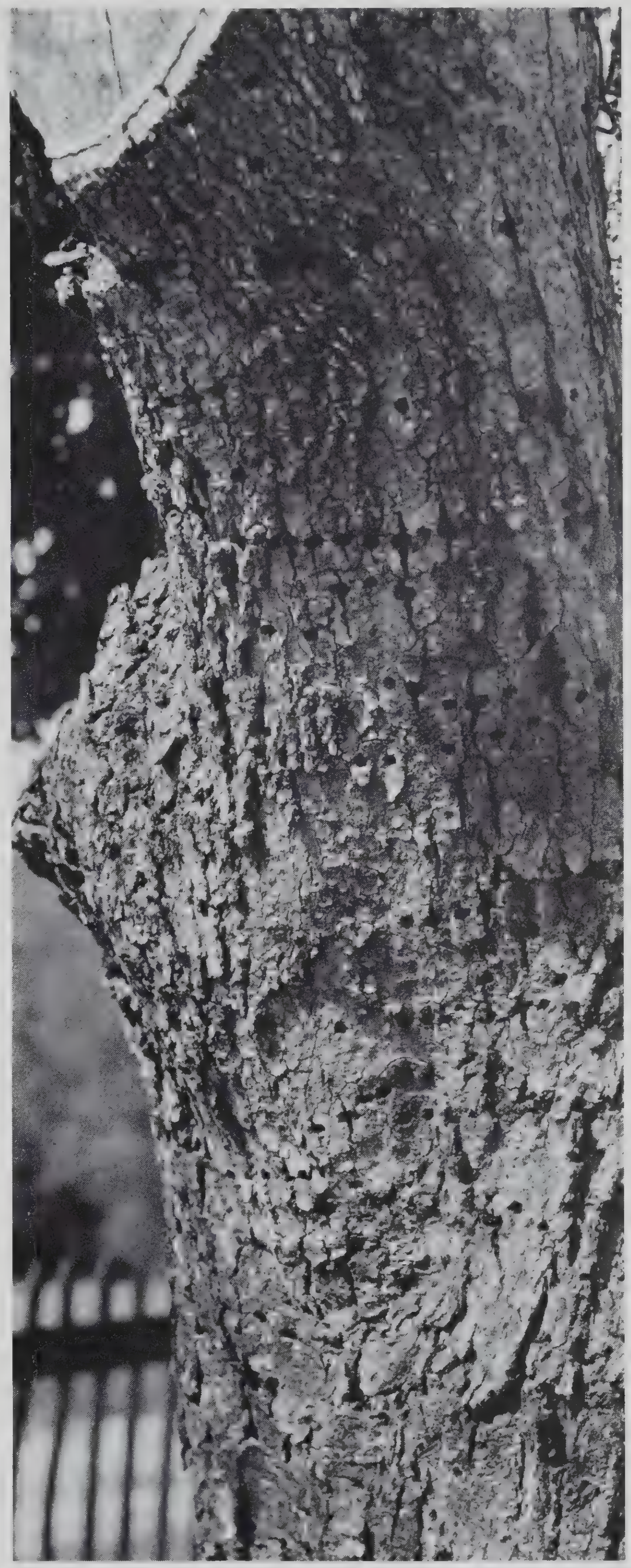


Fig. 37.—Yellow-bellied sapsucker drill holes on a mature sugar maple, a favorite food source of this bird.

food in November). Cambium was eaten most in winter and spring, constituting about 49 percent of the food in April and only 1.5 percent in November. Interesting is the observation of Southern (1966) of a sapsucker feeding on dead gizzard shad in winter.

In his extensive investigation McAtee (1911) found that the sapsucker attacked no fewer than 246 species of native North American trees, 61 species of native vines, and 31 introduced trees.

In Illinois we have found sapsucker drillings in 88 species of woody plants, 72 of which are listed in Table 14. In southern Illinois woodlands the species most often showing sapsucker drillings (excluding data from small samples) are overcup oak, slash pine, tulip tree, pecan, red cedar, and silver and sugar maples. The high incidence of sapsucker drillings in overcup oak (42.8 percent) is surprising, since all other oaks (660 trees) observed in the south had a combined

Table 14.—Woody plants[a] drilled by the yellow-bellied sapsucker in Illinois.

Species	North		East-Central		South		Site
	Number Examined	Percent Drilled	Number Examined	Percent Drilled	Number Examined	Percent Drilled	
Ash, green (*Fraxinus pennsylvanica*)	51	2.0	...	...	56	5.4	Bottomland woods
white (*F. americana*)	44	0	57	10.5	60	0	Upland woods, urban
Beech, American (*Fagus grandifolia*)	...	...	4	0	121	3.3	Upland woods, urban (central)
Birch, paper (*Betula papyrifera*)	...	...	39	89.7	2	100.0	Urban
river (*B. nigra*)	...	...	...	...	75	0	Bottomland woods
Boxelder (*Acer negundo*)	82	1.2	3	0	69	8.7	Bottomland woods
Butternut (*Juglans cinerea*)	11	27.3	...	...	5	60.0	Upland woods
Catalpa (*Catalpa bignonioides*)	1	0	13	15.4	1	0	Urban
Cedar, Chinese (*Juniperus chinensis*)	...	...	25	60.0	3	0	Urban
red (*J. virginiana*)	93	73.1	...	...	38	31.6	Upland woods
Cherry, black (*Prunus serotina*)	63	4.8	48	14.6	15	0	Bottomland & upland woods, urban
Coffee tree, Kentucky (*Gymocladus dioicus*)	3	0	4	0	12	0	Bottomland woods
Cottonwood (*Populus deltoides*)	56	3.6	62	4.8	61	0	Bottomland woods
Cypress, bald (*Taxodium distichum*)	6	0	5	20.0	59	6.7	Urban, bottomland woods (south)
Elm, American (*Ulmus americana*)	36	28.1	37	37.8	136	6.6	Bottomland woods
Siberian (*U. pumila*)	3	33.3	11	9.1	...	...	Urban
slippery (*U. rubra*)	69	5.8	17	35.3	8	25.0	Bottomland woods
winged (*U. alata*)	...	...	...	...	20	0	Upland woods
Ginko (*Ginko biloba*)	...	...	11	72.7	...	...	Urban
Gum, black (*Nyssa aquatica*)	...	...	...	...	38	5.2	Bottomland woods
sour (*N. sylvatica*)	...	...	3	33.3	38	0	Upland woods, urban (central)
sweet (*Liquidambar styraciflua*)	...	...	32	84.4	115	2.6	Bottomland woods, urban (central)
Hackberry (*Celtis occidentalis*)	37	0	43	0	59	1.7	Bottomland, urban
Hawthorn (*Crataegus* sp.)	...	...	9	33.3	6	0	Bottomland, urban
Hickory, bitternut (*Carya cordiformis*)	13	61.5	2	50.0	25	12.0	Bottomland woods, slopes
kingnut (*C. laciniosa*)	...	...	...	...	62	17.7	Bottomland woods
mockernut (*C. tomentosa*)	...	...	6	66.7	75	25.3	Slopes, upland woods
pignut (*C. glabra*)	...	...	18	44.4	56	10.7	Upland woods
shagbark (*C. ovata*)	68	54.4	104	53.8	127	23.6	Slopes, bottomland woods
sweet pignut (*C. ovalis*)	...	...	...	...	11	0	Slopes, upland woods
Ironwood (*Ostyra virginiana*)	39	20.5	19	57.9	15	0	Upland woods, slopes
Larch, European (*Larix decidua*)	...	...	31	3.2	...	...	Urban
Linden, American (*Tilia americana*)	84	23.8	62	79.0	3	33.3	Slopes, upland woods, urban
Locust, black (*Robinia pseudoacacia*)	...	...	25	0	11	0	Upland woods
honey (*Gleditsia* sp.)	3	0	48	0	26	4.2	Urban, bottomland woods
Magnolia (*Magnolia grandiflora*)	...	...	...	...	29	75.9	Urban
Maple, Norway (*Acer platinoides*)	...	...	24	8.3	...	...	Urban
silver (*A. saccharinum*)	132	3.0	149	16.1	240	27.5	Bottomland woods
sugar (*A. saccharum*)	100	53.0	60	88.3	158	25.9	Woodland slopes
Mulberry (*Morus* sp.)	15	0	28	0	1	0	Bottomland woods
Musclewood (*Carpinus caroliniana*)	...	...	...	...	60	8.3	Bottomland woods and slopes

drilling incidence of only 1.5 percent. A rather uncommon tree, the butternut, showed a high incidence (60 percent of 5 trees). Many southern forest trees, e.g., ashes, sweet gum, hackberry, and sycamore, which were fairly abundant were little used by sapsuckers.

Which trees are drilled may depend upon the sugar content of the sap (Kilham 1964), but the species of trees preferred by sapsuckers may be determined by more than the sugar content of the sap. Other chemical constituents (e.g., tannins in oaks, Havera et al. 1976) may influence the birds' preferences. It seems providential for the sapsucker that sucrose and raffinose sugars in tree saps increase greatly in late winter and early spring (Anderssen 1929; Zimmermann & Milburn 1975), a time when other food sources may be scarce. The increase of sap and its nutrient content at an injury site (Kilham 1964) also benefits the bird and may have been instrumental in the evolution of the habit of sap sucking.

In east-central Illinois woods the favorite trees for sapsuckers, based on drilling frequencies, were sugar maples, lindens, pignut and shagbark hickories, and ironwood. Williams (1975) found that sapsuckers in his study area in east-central Illinois spent more time on hickories than on any other trees. In an urban situation (Urbana, Illinois) the trees most often drilled by sapsuckers were paper birch, Austrian and Scotch pine, tulip tree, linden, sweet gum, ginko, and Chinese cedar. In northern Illinois (La Salle, Ogle, and Winnebago counties) the trees most often drilled were red cedar, shagbark hickory, sugar maple, and Scotch pine.

Considering that winter sapsuckers are primarily bottomland forest birds, the trees in upland woods showed a surprisingly high incidence of sapsucker drilling (Table 14). Migrant sapsuckers may be just as plentiful in upland as in bottomland forest. The total amount of forest in an area may help to determine which trees sapsuckers will drill, the birds using upland forest or urban trees to a greater extent when there is little native bottomland forest in an area.

Some tree species showed a gradation in the inci-

TABLE 14.—Continued.

Species	North		East-Central		South		Site
	Number Examined	Percent Drilled	Number Examined	Percent Drilled	Number Examined	Percent Drilled	
Oak, black (*Quercus velutina*)	92	0	30	0	81	0	Slopes
bur (*Q. macrocarpa*)	19	26.3	67	28.4	4	0	Bottomland woods
cherrybark (*Q. falcata pagodaefolia*)	...	...	...	...	34	0	Bottomland woods
overcup (*Q. lyrata*)	...	...	...	...	28	42.8	Bottomland woods
pin (*Q. palustris*)	...	...	42	23.8	70	1.4	Bottomland woods
post (*Q. stellata*)	...	...	...	...	99	3.0	Upland woods
red (*Q. rubra*)	37	0	103	1.9	105	0	Slopes
shingle (*Q. imbricaria*)	...	...	9	0	8	0	Upland edges of woods
Shumard's (*Q. shumardii*)	...	...	3	0	38	2.6	Bottomland woods
white (*Q. alba*)	101	1.0	80	10.0	200	1.0	Upland woods
yellow chestnut (*Q. muhlenbergii*)	...	...	...	...	21	9.5	Slopes
Olive, Russian (*Eleagnus angustifolia*)	...	...	12	100.0	...	...	Urban
Pecan (*Carya illinoiensis*)	...	...	...	...	61	31.1	Bottomland woods
Persimmon (*Diospyros virginiana*)	...	...	8	0	21	0	Upland, urban (central)
Pine, Austrian (*Pinus nigra*)	...	...	49	98.0	...	...	Urban
loblolly (*P. taeda*)	...	...	...	...	138	21.0	Forest plantations
Scotch (*P. sylvestris*)	38	97.4	62	87.1	...	...	Forest edge plantation
short-leaf (*P. echinata*)	...	...	...	...	86	23.3	Upland woods
slash (*P. caribaea*)	...	...	...	...	82	32.9	Forest edge plantation
western yellow (*P. ponderosa*)	20	0	...	...	...	...	Forest edge plantation
white (*P. strobus*)	167	25.1	35	8.6	15	20.0	Upland woods (north), urban & plantation
Redbud (*Cercis canadensis*)	3	0	30	0	3	0	Upland woods, urban
Sassafras (*Sassafras albidum*)	...	...	8	0	22	0	Upland woods
Sycamore (*Platanus occidentalis*)	18	27.3	63	20.1	97	1.0	Bottomland woods, urban (central)
Spruce, Norway (*Picea abies*)	77	9.1	36	19.4	...	...	Forest plantation, urban
Sugarberry (*Celtis laevigata*)	...	...	...	...	34	0	Bottomland woods
Sumac, staghorn (*Rhus typhina*)	...	...	10	0	...	...	Urban
Tree-of-heaven (*Ailanthus altissima*)	...	...	28	0	...	...	Urban
Tulip tree (*Liriodendron tulipifera*)	...	...	39	74.4	51	37.3	Upland woods, urban (central)
Walnut (*Juglans nigra*)	23	21.7	43	18.6	44	11.4	Upland woods, urban
Willow, black (*Salix nigra*)	58	6.9	6	50.0	6	0	Bottomland woods

[a] Tree species of which fewer than 10 occurred in our sample for the state have been omitted from this table.

dence of sapsucker use from the northern part of the state to the southern part, e.g., the silver maple (Table 14). It would be interesting to know if there is a gradient in the sugar content of the sap from north to south in the silver maple. We noted that different tree species were drilled in different parts of the tree and that different species were apparently attacked at different ages. Sugar and silver maples were often drilled at the base of the trunk when the tree was fairly large (old). On the other hand, shagbark hickories were often drilled at the 10- to 15-foot level while the tree was fairly young. Inspection from the ground level may give an erroneous impression of the incidence of use by sapsuckers of a certain tree species. For instance, the bur oak appears to be attacked while fairly young. Later growth and the increase in heavy corky bark tends to obscure old drill holes. Cottonwoods appear to be drilled fairly high in the tree while the tree is fairly young; thus, examinations of old cottonwoods may not allow a ready view of sapsucker holes from the ground level.

The locations of trees appear to influence the incidence of sapsucker attacks also. The presence of a more desirable (to the sapsucker) species may reduce the use of a less desirable tree species in the immediate vicinity. Thus, in a grove of Scotch and Austrian pines, about 10 percent of the Scotch pines were used though the Austrian pines were all heavily drilled. In another location, which had only Scotch pines, 85 percent of them were drilled by sapsuckers. In some locations only less preferred trees occur, and in these places such trees may be used of necessity, which might account for the frequent drilling in parks and urban plantings of sweet gum and sycamore, species relatively little used in the native woodlands that we examined. We also wonder if certain introduced tree species are more vulnerable to sapsuckers because no sapsuckers occur in the original ranges of these trees, and hence, no defense mechanism has been evolved by them. This lack of defense might explain the high incidence of sapsucker attacks on certain introduced pines (e.g., Austrian and Scotch pines) as compared with native pines (e.g., white pine and short-leaf pine). In New Hampshire Kilham (1964) found that sapsuckers were more likely to attack trees which had previously been injured.

In addition to the woody plants listed in Table 14, we also found sapsucker holes in these species: common apple (*Malus pumila*), arbor-vitae (*Thuja occidentalis*), horse chestnut (*Aesculus hippocastanum*), Zumi crabapple (*Malus zumi*), grape (*Vitis* sp.), American holly (*Ilex opaca*), magnolia (*Magnolia soulangeana*), black maple (*Acer nigrum*), osage orange (*Maclura pomifera*), paw paw (*Asimina triloba*), jack pine (*Pinus banksiana*), red pine (*P. resinosa*), poison ivy (*Rhus radicans*), white poplar (*Populus alba*), rowan (*Sorbus aucuparia*), and weeping willow (*Salix babylonica*). These species were not listed in Table 14 because of sample size (fewer than 10 trees observed). McAtee (1911), Gault (unpublished notes 1891–1921), and Wright (1926) observed sapsucker damage on these additional species in Illinois: red maple (*Acer rubrum*), flowering dogwood (*Cornus florida*), magnolia (*Magnolia tripetala*), shadbush (*Amelanchier* sp.), garden plum (*Prunus domestica*), and lilac (*Syringa* sp.).

The present list obviously does not quantitatively reflect Illinois tree populations. The list is far from complete and does not include large portions of Illinois, but more important than a complete list are quantitative data on the relationship between sapsucker populations and tree populations. Swink (1965) found the trees most frequently attacked by sapsuckers at Morton Arboretum, Lisle, were "pines," "spruce," tulip tree, sugar maple, basswood, and cottonwood. He pointed out that sapsuckers showed a preference for the tops of cottonwoods, which is where we also often see them working near the ends of the higher vertical branches. Swink's (1959) study of perching sites of sapsuckers, mainly in April in northeastern Illinois, showed the most frequently used trees to be American elm, cottonwood, sugar maple, linden, white oak, black locust, slippery elm, and white ash.

Sapsuckers can be very destructive to trees, disfiguring or even killing them. It usually takes several years of sapsucker attacks to kill a tree, and even then the direct cause of death may be some other agent, such as fungus or bacteria that invade the sapsucker wounds. We have found no reference to economic damage to forests by sapsuckers in Illinois, where the sapsucker winter populations are relatively low, but the problem has been serious in areas further south (McAtee 1911). Sapsuckers have, at times, been a local problem in southern Illinois orchards, but the extent of the problem has never been measured quantitatively. Complaints about sapsucker damage to yard plantings seem to be increasing in Illinois, both in our experience and that of Eugene Himelick, plant pathologist, Illinois Natural History Survey. To some extent, this increase probably reflects the greatly increased human population in urban areas and the accompanying cost of, and pride in, landscape plantings.

HAIRY WOODPECKER
(Dendrocopos villosus)

(Fig. 38 and 39)

Spring Populations

There is no evidence of migration in Illinois populations of the hairy woodpecker. Our counts of this species are consistently low, and the spring counts (Fig. 40) show less day-to-day variation through the season than those for any other woodpecker except the pileated, also a non-migratory species.

Distribution

The hairy woodpecker has a very wide distribution in North and Central America (Fig. 39). In Illinois the species is probably to be found the year around in nearly every township though published records are still lacking for large areas of the state (Fig. 41).

Nesting Habitats and Populations

The hairy woodpecker is essentially a forest species in summer with very low populations, or none at all, in other habitats. The species occupies both up-

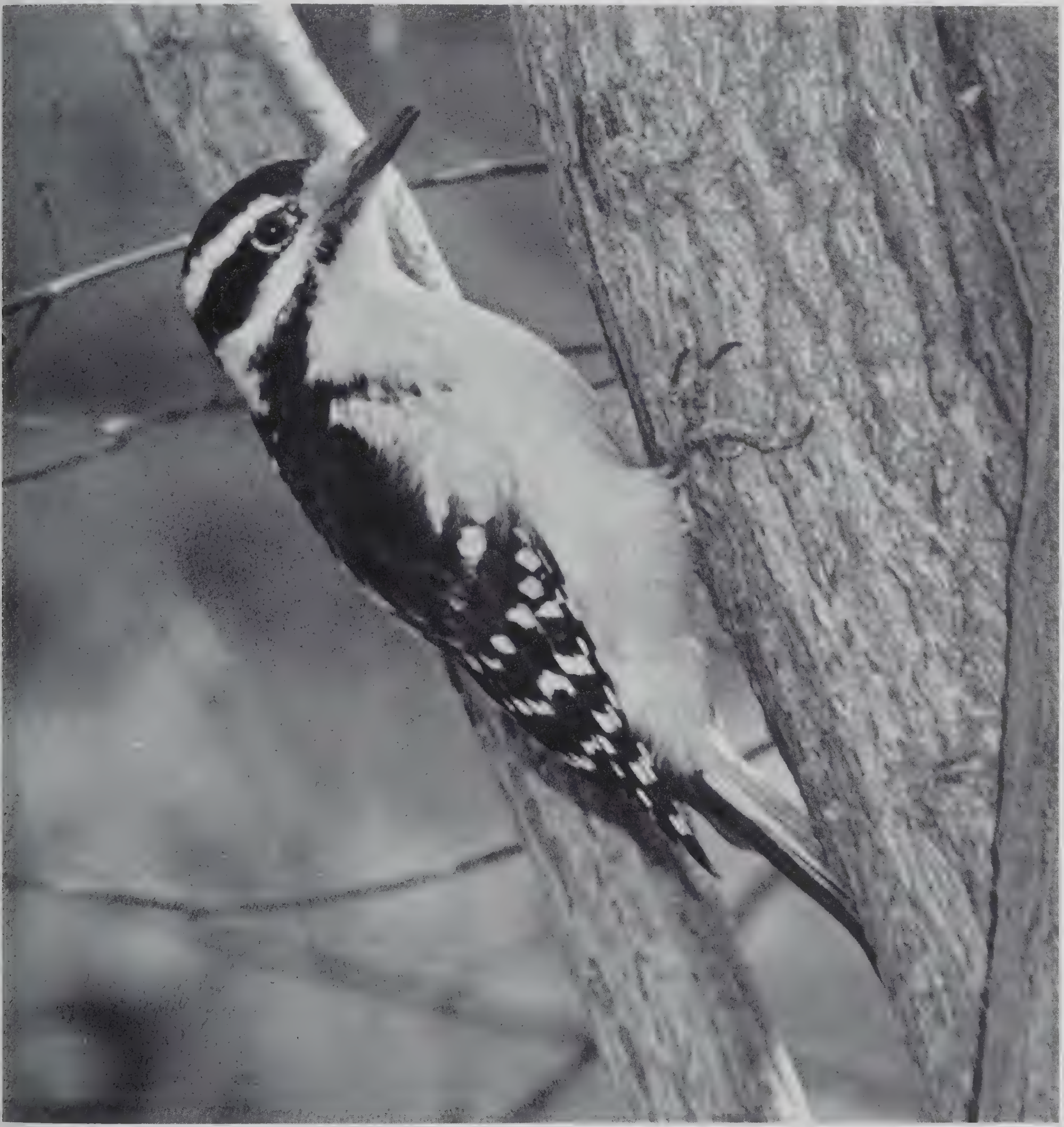


Fig. 38.—Hairy woodpecker. The strong bill and immaculate outer tail feathers are characteristic of the species (compare with downy woodpecker, Fig. 44).

land and lowland forest, apparently favoring bottomland woods at least in central and southern Illinois. Gates (1911) called the hairy a dominant species of both bottomland woods and the more mesic upland forest. In our censuses of southern Illinois forests, we found more hairies, on average, in bottomland woods than upland (Table 15). The highest populations (10–24 birds per 100 acres) have been recorded in virgin or mature bottomland forest in central Illinois (Table 15). There are no measurements of hairy populations in bottomland woods for northern Illinois, but Schafer's 1914–1923 unpublished censuses of upland forest in Rock Island showed high populations for that habitat compared to those in the central and southern regions (Table 15). Our strip censuses in 1957 and 1958 in the north, of 177 acres (about 16 miles) of forest (nearly all upland), did not intercept a single hairy! The observation implies a population decline since Schafer's studies.

In northeastern Illinois Swink (1959 and 1965) noted that hairy woodpeckers showed a definite preference for oaks, especially white oak forest.

Considering the relative abundance of its smaller counterpart—the downy—the hairy woodpecker is surprisingly uncommon in Illinois, and the available data indicate that it always has been (Ridgway 1881*a*; Nelson 1876–1877; Du Bois 1918; Cahn & Hyde 1929). On the Illinois River Barnes (1890) found the hairy to be fairly common, but later (Barnes 1912) observed that the species had become rare. He placed the blame for the change on the house sparrow, which, he said, appropriated almost every hairy woodpecker nest in the area and even killed nestlings of the woodpecker (Bent 1939 ascribed this observation to Benjamin Gault). In general, the population measurements for the hairy suggest a continuing decline. Both Barnes (1890) and Ridgway (1887) refer to the nesting of hairy woodpeckers in orchards, a habitat not now used at any significant population level. Even in earlier times, however, hairy woodpeckers were rare in man-dominated habitats, including residential habitat (Ridgway 1887). The only other reference to interspecific aggression is that of Stickel (1963), who described the conflict between a nesting pair of hairy woodpeckers and red-bellies nesting in the same tree.

Hairy woodpecker habitat has not been analyzed precisely. Silloway (unpublished manuscripts 1922 and 1923) repeatedly refers to hairy woodpeckers as being in "large trees" or on "big tree trunks" in contrast to the downy woodpecker. There were no correlations between summer numbers of hairy woodpeckers and any feature or characteristic of the southern Illinois woodlands examined by us in detail (see introduction to this paper). Nor was there any apparent relationship between this woodpecker and other woodpecker species. Such relationships are hard to discern in a species with such low population levels as the hairy woodpecker has at present. The greatest number of hairies in any of these southern woodlands was 5.4 birds per 100 acres in one woodland in 1974 and 5.2 birds per 100 acres in another in 1975. There were over three times as many hairies per acre in the eight bottomland woods as in the five upland woods studied (Table 15).

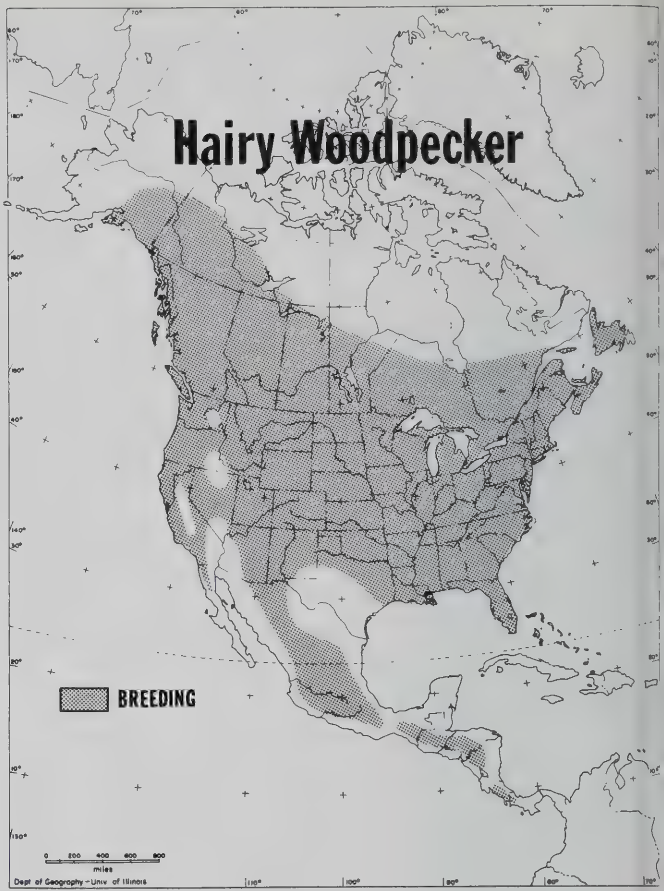


Fig. 39.—General distribution of the hairy woodpecker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat.

Hairy woodpecker territories measured in McLean County by Calef (1953*a*) in mature bottomland forest ranged from 1.6 to 3.7 acres, averaging 2.6 acres. Also in central Illinois (Piatt County) Allison (1947) measured one territory—6.5 acres—in mature upland forest. This territory was more than twice the size of downy woodpecker territories (average of four: 2.7 acres) in the same area.

There are site data for only 17 hairy woodpecker nests, mainly in northern and central Illinois. About one-third of the nests were in dead branches of living ashes, elms, and birches; one-third in dead trees or stumps; and one-third in living willows, elms, oaks, and maples. Most of the nests were 15–35 feet high, but one was as low as 5 feet (Hess 1904).

Nesting Cycle

There are only fragmentary data on the nesting cycle of the hairy woodpecker in Illinois. In Central Illinois Fawver (1947*a*) observed hairy woodpeckers establishing territories about the first week in April, but some courtship behavior begins before then. In northeastern Illinois Gault (unpublished notes 1906, 1907, and 1927) referred to what he called "mating" or "courtship" behavior by hairies in aggregations of four or more birds throughout March. Vocalizations have not been studied in Illinois, but Lawrence (1967) pointed out that the hairy's courtship display involves rather spectacular bounding flights.

Hess (1910) considered the hairy to be the earliest nesting woodpecker in the Philo area. If cavity excavation has been observed in Illinois, the observation has not been published. Hairy woodpecker nest cavities in Illinois have varied from 10 to 15 inches in depth, with entrance holes ranging from 1½ to 2½ inches in diameter (Loucks unpublished notes 1893; Fawver 1947*a*; Calef 1953*a*). One cavity was 4½ inches wide (Chicago Museum of Natural History oology specimen label 16552). Link (1945) stated that the cavity entrance for the hairy woodpecker was 1¾ inches in diameter, and Ford (1939) gave these specifications for a cylindrical nest box for the hairy: floor, 6 inches in diameter; depth, 12–15 inches; entrance above floor, 9–12 inches; and diameter of entrance, 1½ inches, the box to be placed 12–20 feet high. We know of no case of the use of a nest box by the hairy in Illinois.

Like the rest of the cycle, the egg-laying season of the hairy woodpecker is poorly known in Illinois. The eggs are the typical immaculate glossy white of woodpeckers. In central Illinois Hess (1904) referred to a nest with four eggs on 24 April, and there is a Chicago record of a nest with two eggs on 30 April (Anonymous 1877). Most of the "fresh-egg" sets in museum collections and those referred to in the literature were laid in May, especially 1–20 May. However, there are references that indicate much earlier laying. Sanborn (1922*a*) found two nests on the Kankakee River in the period 20–22 May, with young ready to fledge, and R. M. Barnes (Chicago Museum of Natural History oology specimen label 7340) referred to a nest at Lacon with three addled eggs and one young ready to fledge on 8 May. If we assume an incubation period of 11–12 days and a nestling period of 28–30 days

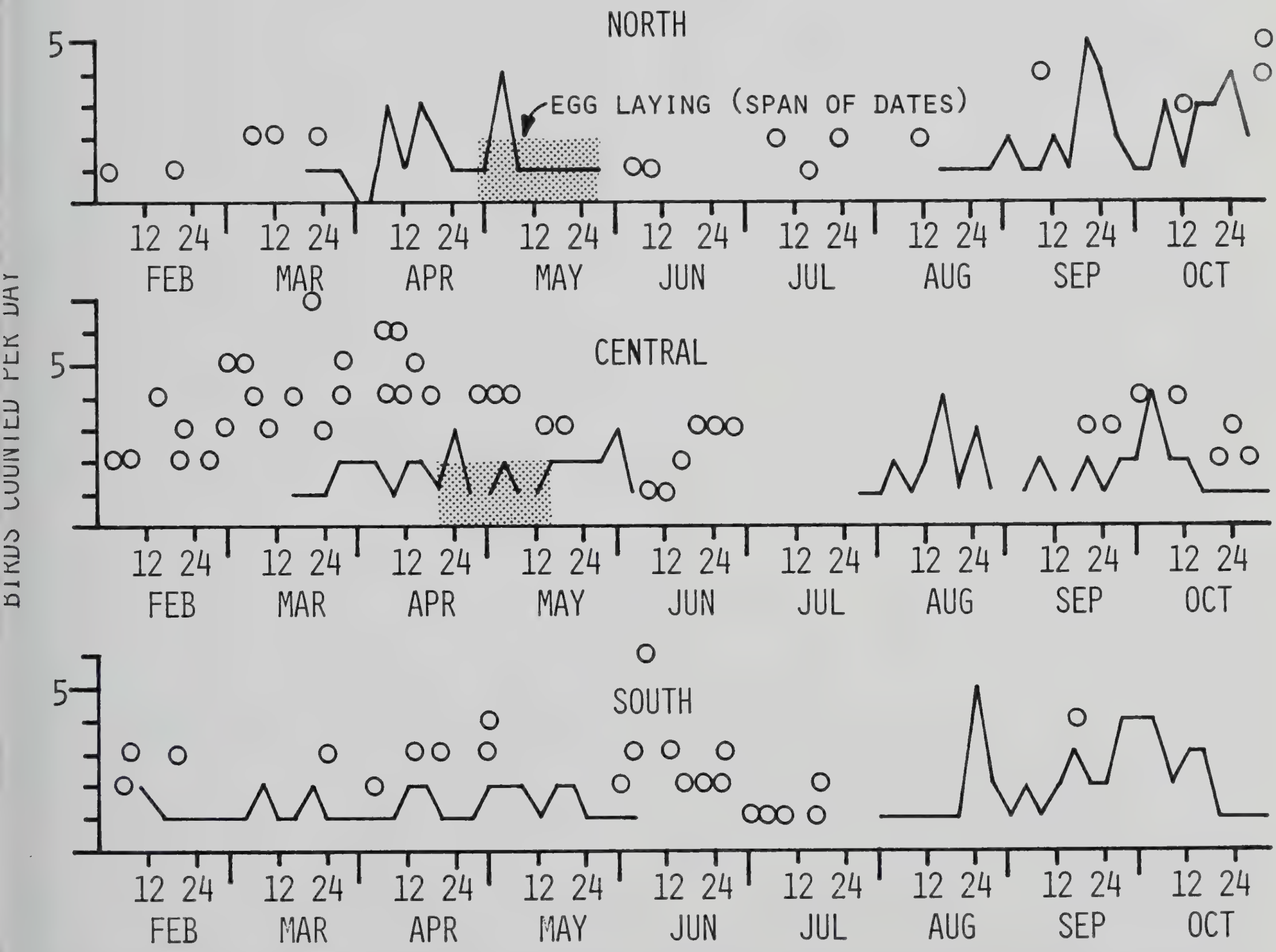


Fig. 40.—Numbers of hairy woodpeckers seen throughout the spring and fall seasons, with the span of egg-laying dates shown by the stippled area. The graph line represents higher count of each 4 days of a continuous record (1967–1970). Hollow circles represent counts from other years or other observers.

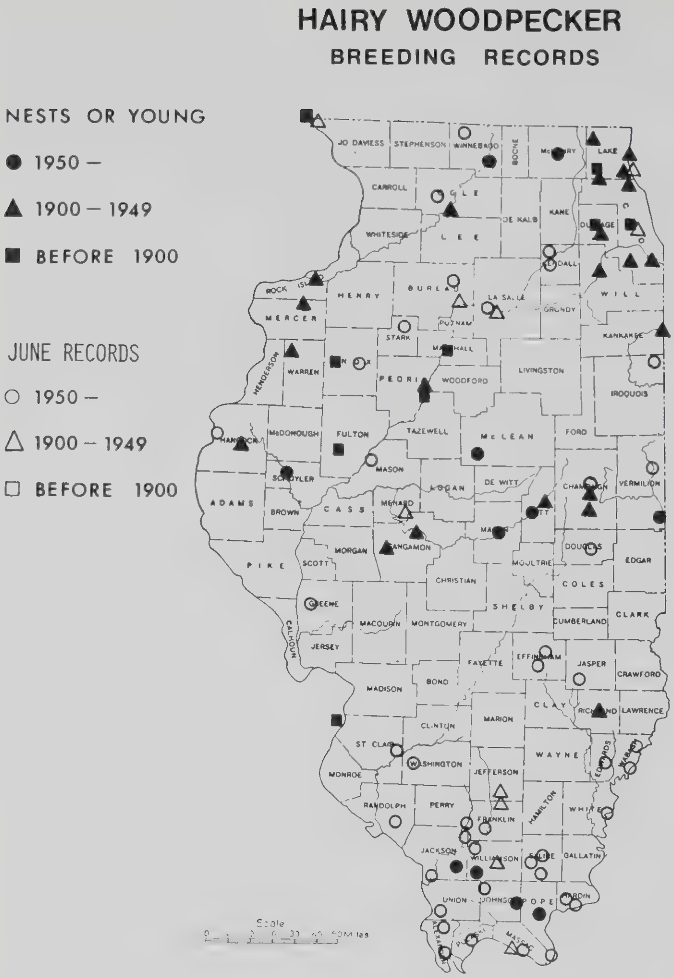


Fig. 41.—Distribution of breeding records of the hairy woodpecker in Illinois. Hollow symbols represent birds seen or heard in June.

(Lawrence 1967), eggs in the Kankakee nest could have been laid as early as 9 April, and those in the Lacon nest might have been laid even in late March, depending upon how near the young were to fledging. There are no egg-laying dates for southern Illinois.

We have found clutch data on only 13 Illinois nests with eggs, none in the south. The distribution of clutches was: six eggs, two nests; four eggs, eight nests; and three eggs, three nests. The absence of five-egg sets is probably only an accident of the small sample. Hess (1904) pointed out that the incubating adult sits very close and is difficult to dislodge from the eggs.

Most nests have been found with young fairly well grown, as the young are often noisy then and conspicuous.

There are no data on nesting success or productivity.

Fall Populations

The events of late summer and fall among the hairy woodpecker populations of Illinois are particularly obscure. Though no migration is known, there is some movement by at least part of the population to nonforest habitats, including most notably urban residential areas. We first noted a hairy in open country on 13 September in the south.

We have seen hairy woodpeckers in what appeared to be fresh plumage as early as 4 September, and others obviously in heavy molt on 11 September. George (1972) observed that it took about 4 months for juvenile hairies to complete the molt and pointed out that some juveniles may still be aged on the basis of their primaries well into October.

Table 15.—Breeding populations of hairy woodpeckers in Illinois.

Habitat	Acres	Birds per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Oak-maple forest	55	0–7 (avg 3.2)	1927–1975	Map	Champaign (C)[b]	Kendeigh 1944
Oak-maple forest	64	9	1943	Map	Champaign (C)	Johnston 1947
Forest (all types, including edge)	214	1–4 (avg 2.8)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	340	2–4 (avg 2.6)	1957–1958	Strip	South	Graber & Graber 1963
Forest (unspecified)	20	10	1914–1916	Nest	Rock Island (N)	John J. Schafer (unpublished notes 1914–1923)
Forest (unspecified)	54	4–9 (avg 7.1)	1917–1923	Nest	Rock Island (N)	John J. Schafer (unpublished notes 1914–1923)
Mature upland forest	479	0–1 (avg 0.4)	1974–1975	Strip	South	This paper
Mature bottomland forest	1,077	0–5 (avg 1.3)	1973–1975	Strip	South	This paper
Virgin floodplain forest	77	10	1948	Map	Sangamon (C)	Snyder et al. 1948
Virgin floodplain forest	50	4	1947	Map	Piatt (C)	Fawver 1947*b*
Mature bottomland forest	63	17–24 (avg 20.6)	1950–1951	Map	McLean (C)	Calef 1953*a*
Upland second-growth oak-hickory forest	56	4	1941–1942	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*
Upland oak-hickory forest	24	4	1967	Map	Hancock (C)	Franks & Martin 1967

[a] All figures were converted to birds per 100 acres (territorial males or nests × 2).
[b] C refers to the central region of Illinois and N to the northern, as shown on winter distribution maps, e.g., Fig. 5.

Our daily counts of hairy woodpeckers in the state were higher in fall (August–October, inclusive) than in spring (March–May, inclusive) but only slightly: 1.3 in fall to 1.0 in spring. The ratio was higher in both the north (2.1:1.0) and south (1.5:1.0), but in central Illinois the ratio (1.0 to 1.2) showed a slight decline in fall. The data seem to indicate poor productivity. Banders should make an effort to get age ratios on this species in fall, using the primary character (George 1972).

Winter Populations

The hairy woodpecker is to be expected in every county in winter, and the absence of records for a number of counties is probably only indicative of a shortage of study in those areas (Fig. 42). Hairies are regularly detected on virtually all Christmas counts. Several observers, particularly in northern Illinois, have noted that hairies are conspicuously more common in winter than in summer (Nelson 1876–1877; Eaton 1878; Smith & Beecher 1958). At least a few hairy woodpeckers move to more open habitats in winter, but this is not a major population shift (Table 16). In the south, however, there is a notable shift by hairies to greater use of urban residential habitat and upland forest in winter. In our 1974–1976 censuses in the south, winter population density, on the average, declined slightly from summer levels in bottomland but increased in upland forest.

The winter population densities from the cross-country censuses of 1907 and 1957–1958 indicate a decline of the hairy, at least in southern Illinois, where the largest samples were taken (Table 16). The Christmas counts also show a downward trend since 1900 (Fig. 43). As there were few counts in the south in the early years, the data for that region are the least dependable. On the other hand, the northern and central counts show the same pattern, and their 5-year averages (Fig. 43) are significantly correlated ($r = 0.924$, $P = < 0.001$).

Cooke (1885*b*) called the hairy woodpecker abundant in Union County and reported seeing 10–20 per day. Our highest count during the forest censuses (two observers in one party) was six hairies in 4 hours —also in Union County.

The numbers of hairy woodpeckers in winter show positive correlations with the numbers of large trees per acre (trees over 22 inches DBH) both in upland and bottomland habitats ($r = 0.987$ and 0.910, respectively, $P = < 0.001$). They also show positive correlations with the diversity of genera and species of large trees. For upland woods the correlation between the number of genera of large trees and the number of hairy woodpeckers is 0.953 ($P = < 0.01$) and for the species it is 0.996 ($P = < 0.001$). For bottomland woods the correlation was 0.828 for number of genera of large trees and 0.822 for number of species ($P = < 0.01$). In other words, in winter this woodpecker seems to prefer mature woods with a variety of large trees present.

There may be some competition or conflict between hairy woodpeckers and red-headed woodpeckers. There is a negative correlation between the numbers of these two species ($r = -0.772$, $P = < 0.02$) in bottomland woods. Conversely, the numbers of hairy and red-bellied woodpeckers showed a positive correlation in six of the eight bottomland woods examined ($r = 0.768$, $P = <0.05$).

Food Habits

There are numerous references to hairy woodpeckers at feeders, especially at suet (Childs 1922; Lampert 1922; Patterson 1923; Cone 1956). At a feeder in Ottawa, Bellrose (1934–1935) observed the hairy to be shyer than the downy but dominant over the smaller species in conflicts. At Glen Ellyn, Gault (unpublished notes 1894 and 1914) observed a hairy feeding on poison ivy fruit in October. In Union County in winter

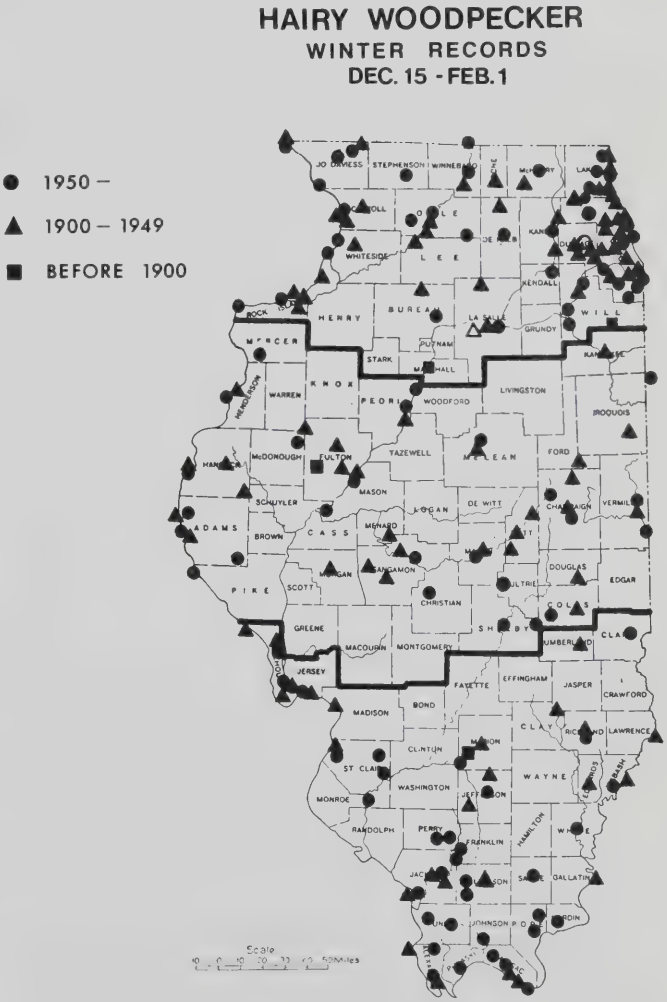


Fig. 42.—Distribution of winter records of the hairy woodpecker in Illinois. The three regions of the state referred to in the text are separated by the two heavy horizontal lines.

Table 16.—Winter populations of hairy woodpeckers in Illinois.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Urban residential	355	0	1976	Strip	North & Central	This paper
Urban residential	191	1–4 (avg 2.1)	1976	Strip	South	This paper
Suburban woodlot	20	10	1968–1972	Map	Lake (N)[a]	Miller & Miller 1972
Oak-maple forest	55	0–4 (avg 2.5)	1925–1948	Map	Champaign (C)	Kendeigh 1944, 1948*a*
Oak-maple forest	55	2–7 (avg 3.2)	1949–1975	Map	Champaign (C)	Kendeigh et al. 1957; Kendeigh 1973
Forest (all types, including edge)	46	0–2 (avg 1.1)	1940–1941	Map	Piatt (C)	Johnston 1942
Forest (all types, including edge)	65	3	1907	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	45	0	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	50	2	1907	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	152	3–6 (avg 4.6)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	241	3	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	0–2 (avg 0.9)	1957–1958	Strip	South	Graber & Graber 1963
Mature upland forest	772	0–3 (avg 0.9)	1974–1976	Strip	South	This paper
Mature bottomland forest	1,398	0–5 (avg 0.9)	1974–1976	Strip	South	This paper
Bottomland forest	50	2–6 (avg 3.0)	1950–1953	Map	Cook (N)	Montague 1950, 1953
Grazed bottomland woods	53	2–4 (avg 2.5)	1955–1957	Map	Macon (C)	Chaniot & Kirby 1955*b*, 1956; Kirby & Chaniot 1957
Shrubby field and forest edge	70–85	(+)[b]	1948, 1955–1956	Map	Richland (S)	Hundley et al. 1956
Shrubby field and forest edge	40	0–2	1960–1965, 1968	Map	Lawrence (S)	Shaw 1961; Axelson et al. 1965

[a] N refers to the northern region of Illinois, C to the central region, and S to the southern, as shown on winter distribution maps, e.g., Fig. 5.
[b] The plus symbol (+) indicates fewer than one bird per 100 acres.

Cooke (1885*b*) noted that hairy woodpeckers damaged corn in fields adjacent to forest, but Beal's (1911) extensive study of stomach specimens from 33 states showed that corn was an insignificant part of the hairy's diet. His study showed the hairy to have one of the most consistent diets through the year, being about 78 percent animal matter and 22 percent vegetable. In June the animal content went as high as 90 percent.

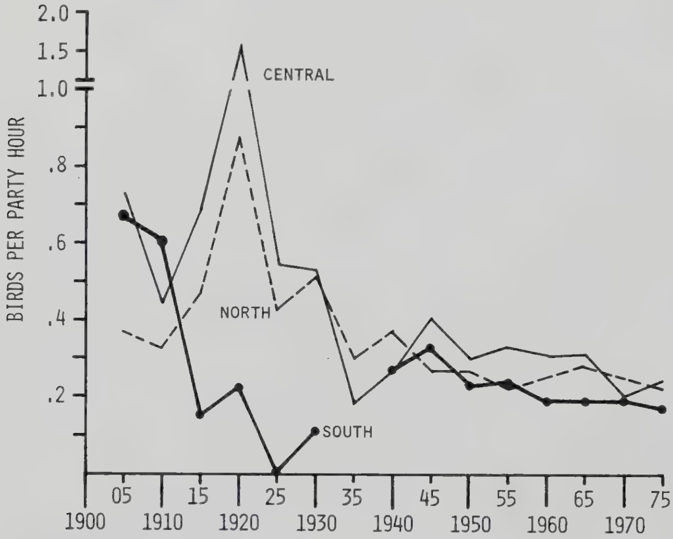


Fig. 43.—Hairy woodpeckers seen per party hour on Audubon Christmas counts in the three regions of the state. Each point represents a 5-year average.

The dominant foods, constituting about 31 percent through the year and reaching as high as 41 percent in December, were the larvae of wood boring beetles, especially Cerambycidae, Buprestidae, and Lucanidae. Some stomachs had large numbers (up to 100) of such larvae. Beal (1911) found ants to be the second most important item in the hairy's diet, constituting about 17 percent (27 percent in January) and, like the borers, present every month. Caterpillars, the third most important food, were also present every month and made up about 10 percent of the food. Webster (1881) and Waldbauer et al. (1970) pointed out the importance of hairy and downy woodpeckers as predators on cecropia cocoons.

Of the vegetable food, Beal (1911) found that about 5 percent of the diet was fruit, mainly wild (sassafras, dogwood, sumac, etc.). About 11 percent was mast, notably beechnuts, hazelnuts, and acorns. Seeds, such as foxtail, vervain, and mustard made up about 4 percent of the diet.

Longevity

Hairy woodpeckers appear to be rather long-lived. Reuss (1963) reported on a hairy woodpecker that was banded in Cook County, 9 November 1952, and returned on 3 November 1963, making it at least 11 years old—the oldest on record in Illinois. Two other hairy woodpeckers (males) banded in northeastern Illinois were at least 7 and 8 years old, respectively (computer printout from U. S. Fish and Wildlife Service Bird Banding Office 1972 and 1974). Bartel's (1964 and 1967) oldest banded hairies were just under 5 years. There are no studies of age distribution for any Illinois population of hairy woodpeckers.

There is but one reference on any mortality factor of the hairy. Brown & Bellrose (1943) found hairy woodpeckers to be 3 of 259 identified prey items of screech owls in southern and central Illinois, probably mainly in winter. Only seven of the prey items were downies—i.e., about twice the number of hairies. Our winter counts indicate a ratio of about six dowines to one hairy in the south, which is also the ratio of the two species in the Christmas counts. The ratio shown in central Illinois Christmas counts was about five downies to one hairy. These observations imply that screech owls are more likely to catch hairies than downies.

Specimen Data

There are several references to the occurrence of two races of hairy woodpeckers in Illinois (Ferry 1907*b*; Howell 1910; Ridgway 1914; and others). Ferry (1907*b*) pointed out that specimens from southern Illinois were small, resembling in that respect the form *D. villosus audubonii* of the southeastern USA. In color, however, the southern Illinois specimens were clear white below, as in *D. v. villosus*. All Illinois specimens we have seen have been thus colored and are probably best referred to the nominate race.

There is a suggestion of size difference between hairies from north of the latitude of Pike County and those from south of Pike County, but presently there are too few specimens available to determine whether the change is consistent and whether it is merely a smooth cline with latitude.

The wing and tail length ranges and means for six northern and central males (worn, molting, and juvenile specimens excluded) were: wing, 118–124 mm (mean: 120.1 mm, SD: 2.23); tail, 74–78 mm (mean: 76.5 mm, SD: 1.16); and for five southern males: wing, 112–118 mm (mean: 115.4 mm, SD: 2.46); tail, 59–71 mm (mean: 67.5 mm, SD: 4.81). Measurements for three northern and central females were: wing, 116–124 mm (mean: 119.3); tail, 70–77 mm (mean: 73.2 mm); and for eight southern females: wing, 110–118 mm (mean: 113.6 mm, SD: 2.44); tail, 63–71 mm (mean: 67.9 mm, SD: 2.75).

We have but four weight records for Illinois hairy woodpecker specimens, one male and three females. Weights of the females, all taken in January–February in southern Illinois, were 58.0, 60.5, and 66.0 grams. A male from Union County weighed 68.5 grams in September.

DOWNY WOODPECKER

(Dendrocopos pubescens)

(Fig. 44 and 45)

Spring Populations

There is no proof that downy woodpeckers migrate in Illinois, despite some suggestions to the contrary (Woodruff 1907; Anonymous 1916; Swink 1959; Graber & Graber 1963). Cooke's (1888) explanation of the downy's apparent population shifts as more or less local winter wandering to forage is probably the most reasonable. The published banding records for downies in Illinois (Cooke 1937 and 1950; Bartel 1959*a*, 1959*b*, and 1964; Lincoln 1924 and 1927) include no record of a recovery very far distant from the place of banding.

The presence of 10 downy woodpeckers among numerous night migrants killed in Lake Michigan during the disastrous storm on the night of 16 April 1960 (Segal 1960) is not necessarily indicative of migration, as the birds may have been blown from perches along the lake shore.

Despite the absence of migration in this species, the pattern of the daily counts of downy woodpeckers (Fig. 46) has peaks in spring and fall similar to the patterns for migratory species. These peaks probably reflect activity related to changes in habitat and habit from winter foraging to nesting and back, as noted by Cooke (1888), Twomey (1945), and Graber & Graber (1963). Twomey (1945) noted this change about 1 May in east-central Illinois.

Distribution

Downy woodpeckers of one form or another occupy nearly all of North America where there are trees (Fig. 45). In Illinois they are probably to be found in every township though the published record is still very incomplete (Fig. 47).

Nesting Habitats and Populations

With the onset of nesting, downy woodpeckers become primarily forest dwellers, particularly of the forest interior (Kendeigh 1944; Twomey 1945). In central Illinois Hess (1910) and Hankinson (1915) noted that downies were more common in lowland forest than in upland, and our data for southern Illinois forests (Table 17) also show downy populations consistently higher in bottomland than in upland. The highest population densities for downies have been recorded in virgin or old lowland forests (Table 17). Shrub areas have population levels similar to those in upland forests. The woody habitat with lowest populations of downies is urban residential habitat (Table 17). Within the bottomland forests sudied by us in southern Illinois, there was a positive correlation between summer numbers of downies and the percentage of the total basal area

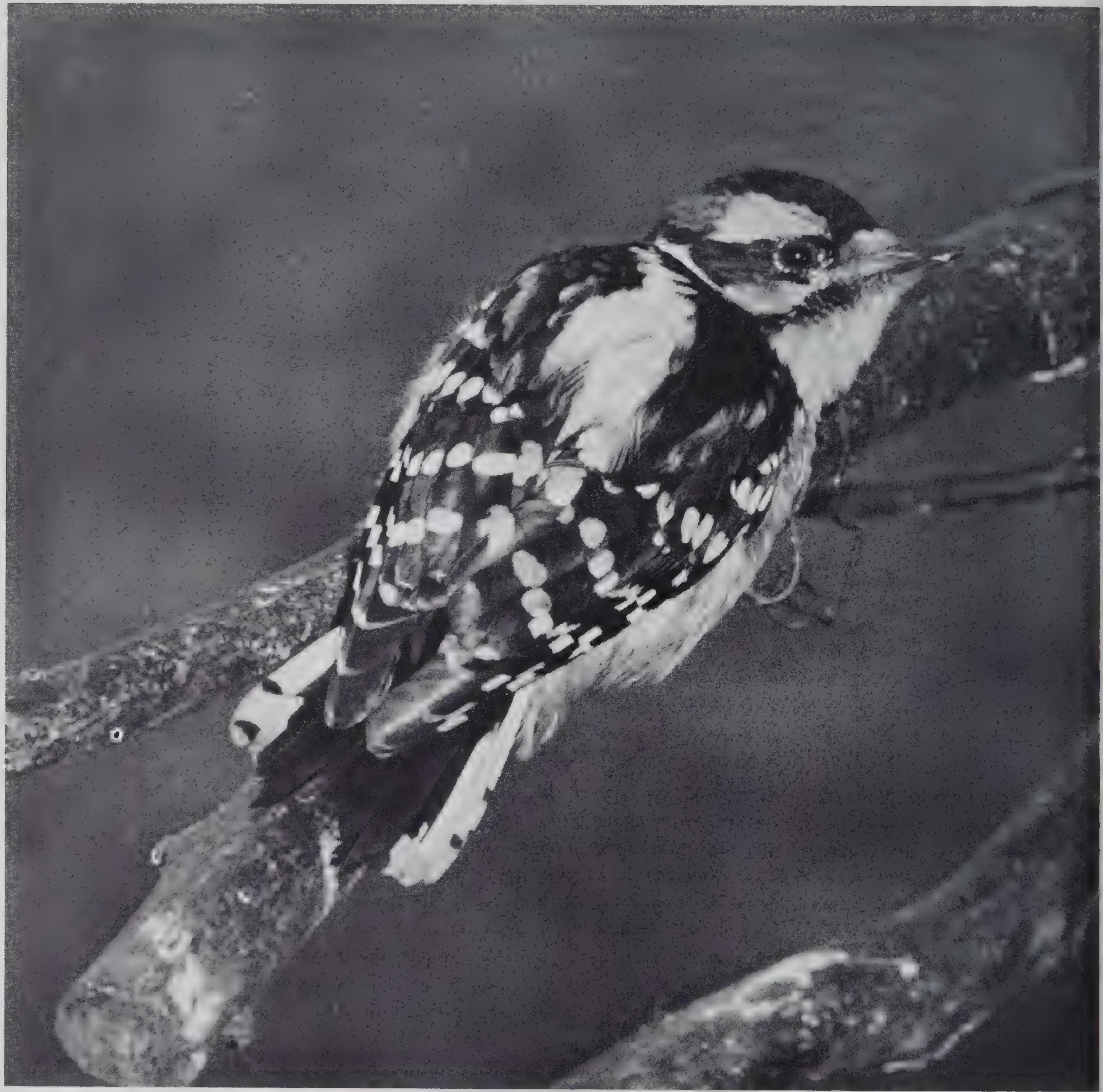


Fig. 44.—Male downy woodpecker. Note the small bill and the bars on the outer rectrices (compare with hairy woodpecker, Fig. 38).

of medium sized trees (10–22 inches DBH) ($r = 0.867$, $P = < 0.01$). We found a negative correlation between downy numbers and the percentage of total basal area contributed by large trees ($r = -0.834$, $P = < 0.01$). There was a positive correlation between downy populations and the numbers of dead trees in the southern Illinois woodlands ($r = 0.799$, $P = < 0.01$). This correlation agrees with observations in central Illinois by Williams (1975), who noted extensive use of dead trees in bottomland woods by downies, although downy woodpeckers did not show the great increase in numbers apparent in the red-head population following a massive tree kill from flooding in Calhoun County (Yeager 1955).

In the upland woods studied by us in southern Illinois, we found no correlations between density (number per acre), basal area, and sizes or kinds of woody plants present and downy numbers. There was a correlation between downies and red-bellied woodpeckers ($r = 0.804$, $P =$ ca 0.05), suggesting that these two bird species prefer similar habitat in the uplands.

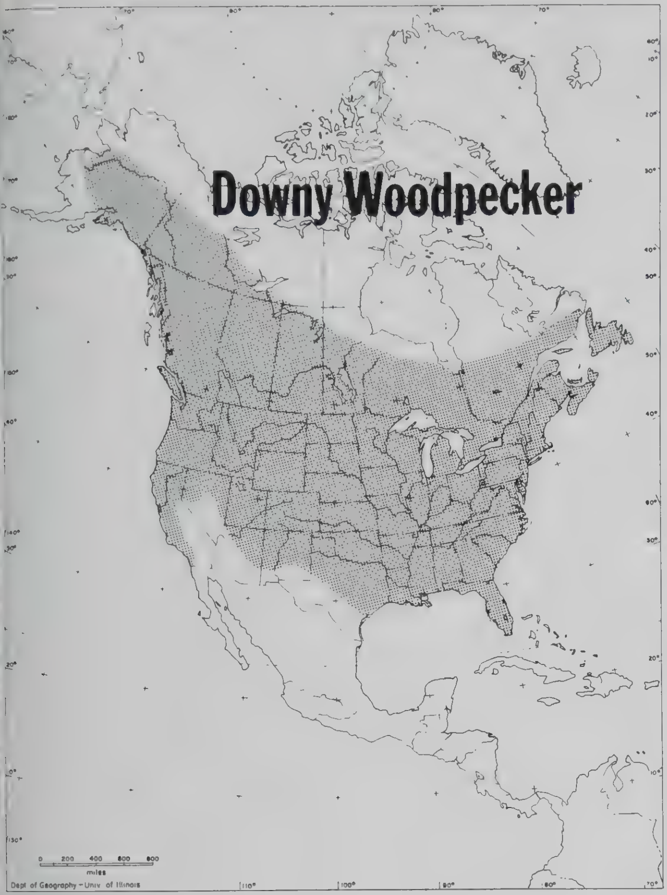


Fig. 45.—General distribution of the downy woodpecker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat.

In northeastern Illinois Swink (1959 and 1965) found that downies were most often seen in white oaks, bur oaks, elms, willows, and hawthorns. William Starrett (personal communication) found downies particularly common in stands of willow on the Illinois River. The most commonly recorded nest trees of downy woodpeckers have been willows and elms, but the vast majority of nests are in dead trees or dead branches of trees, and a variety of species have been used, including willow, red oak, white oak, plum, silver maple, apple, ash, crabapple, shagbark hickory, sassafras, sycamore, and tree-of-heaven. The heights of 41 nests ranged from 4 to 50 feet and averaged 19 feet.

Our observation that downy populations were notably higher in central Illinois than in either the north or south (Graber & Graber 1963) is puzzling, as population densities within a given habitat do not ordinarily change so abruptly. The observation needs corroboration from studies on larger census areas on forest tracts of comparable quality between regions.

Breeding territories of downies in mature lowland forest measured in central Illinois by Calef (1953*a*) and Fawver (1947*b*) ranged from 1.3 to at least 4.7 acres. Calef (1953*a*) measured nine downy territories in 1950 (range: 1.3–3.1 acres, average: 2.0 acres) and four in 1951 (range: 1.3–2.1 acres, average: 1.5 acres).

Nesting Cycle

Johnston (1944) has described the courtship behavior of the downy woodpecker in central Illinois. At such times the birds are noisy, and their chasing episodes often involve three or more birds together. The increased conspicuousness from this behavior probably accounts, to some extent, for the generally high counts in spring (Fig. 46). Musselman (1937) has noted "drumming" behavior by downies as early as 5 January, but active courtship is not usually observed in central Illinois until late February or March, continuing at least through April. The periodicity of neither calling nor drumming has been studied. Jackson (1919) gave phonetics for the common call note as "pique," which, when repeated rapidly, makes a kind of song (trill). Mating and nest excavation have been observed most often in late April in central and northern Illinois (Ford et al. 1934; Coursen 1947; Fawver 1947*a*; Gault unpublished notes 1910), but observations are lacking for the south. The use of nest boxes by downies has never been recorded in Illinois, and is apparently rare, but Ford (1939) recommends these house dimensions for the species: floor, 4 × 4 inches; depth of cavity, 8–10 inches; entrance above floor, 6–8 inches; and diameter of entrance, 1½ inches. Calef (1953*a*) measured natural nest cavities of downies in Funks Grove and found them to vary from 2.5 to 4 inches in diameter and from 7 to 10 inches in depth, with entrance holes 1.1–1.5 inches in diameter. Link (1945) notes the nest entrance to be 1.5 inches for downies. The time requirement for cavity construction has not been recorded in Illinois, but Lawrence (1967) recorded the time at eight nests as 13–20 days. No nest other than the cavity is built.

The earliest egg laying by downies, known to us, was 30 March in southern Illinois and more than a month later in the north (Fig. 46). The duration of the laying season is very poorly known but extends to at least 1 June in the north (Fig. 46). The apparent brevity of the laying season probably reflects more the paucity of study than the actual biology of the species. The eggs, typical of those of woodpeckers, are immaculate white. Twenty-two sets of eggs, mainly old (around 1900) museum specimens from northern Illinois, showed this distribution of clutches: six eggs, 5 (23 percent); five eggs, 14 (64 percent); four eggs, 2; three eggs, 1. The incubation period has not been measured in Illinois, but Lawrence (1967) found the period to be 12 days in Ontario.

Young birds have been observed out of the nest in central Illinois as early as 3 June (Fawver 1947*a*) and in the north by 9 and 10 June (Ford et al. 1934; Sanborn & Goelitz 1915). By mid-June groups of wandering young and adults are common in central Illinois (Weise 1951). The length of nestling life, 20–22 days, is relatively short for a woodpecker, and the duration of parental care extends at least 3 weeks beyond fledging (Lawrence 1967).

Nesting success has never been measured for any Illinois population of downies. Strangely (for a cavity nester) there is no reference in the Illinois literature

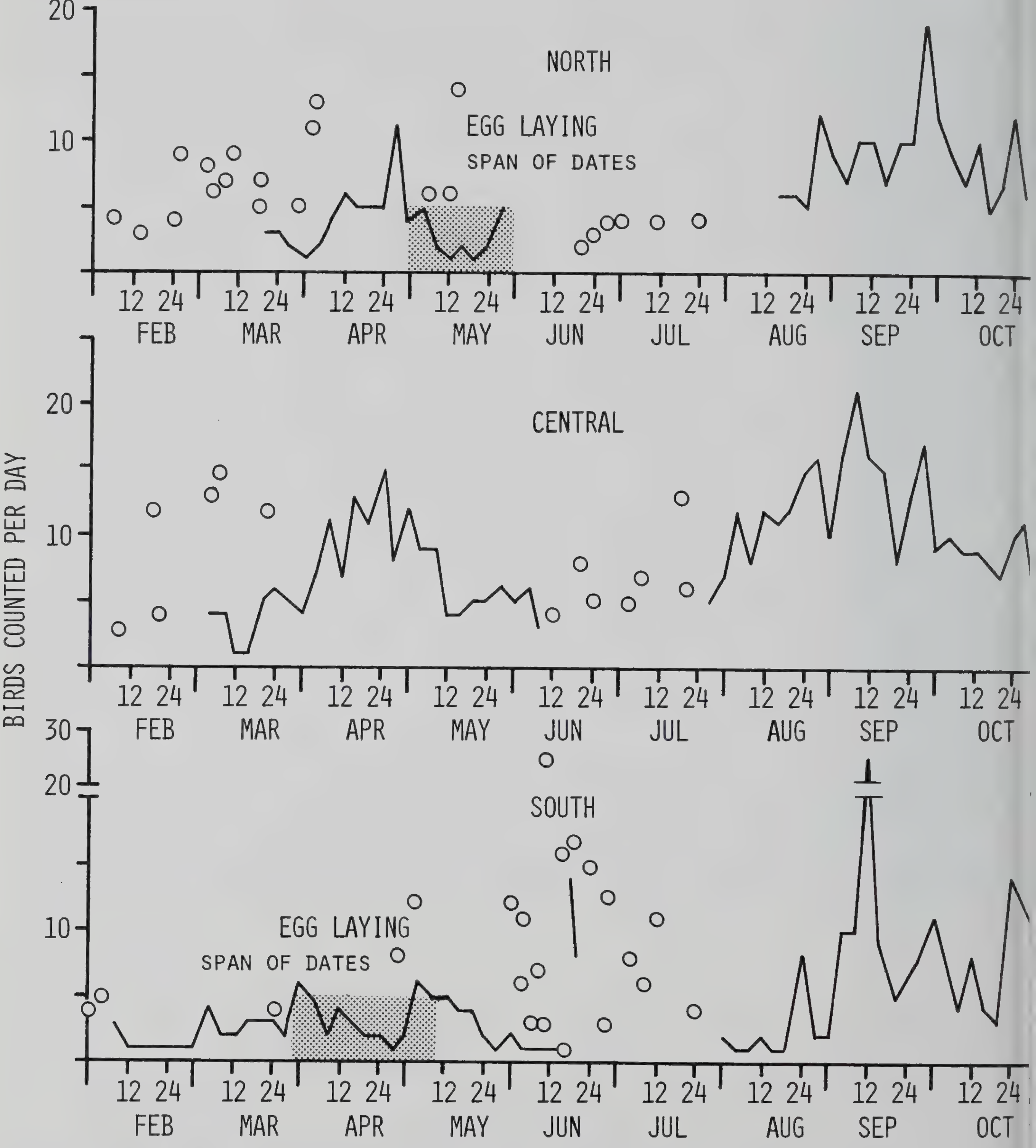


Fig. 46.—Egg-laying season (shaded area) and numbers of downy woodpeckers seen in spring, summer, and fall in the three regions of Illinois. The graph line represents the higher count of each 4 days during spring and fall from a continuous daily record made in 1967 and 1970 in southern Illinois, in 1969 in central Illinois, and in 1968 in northern Illinois. Hollow circles show numbers seen in other years or by other observers.

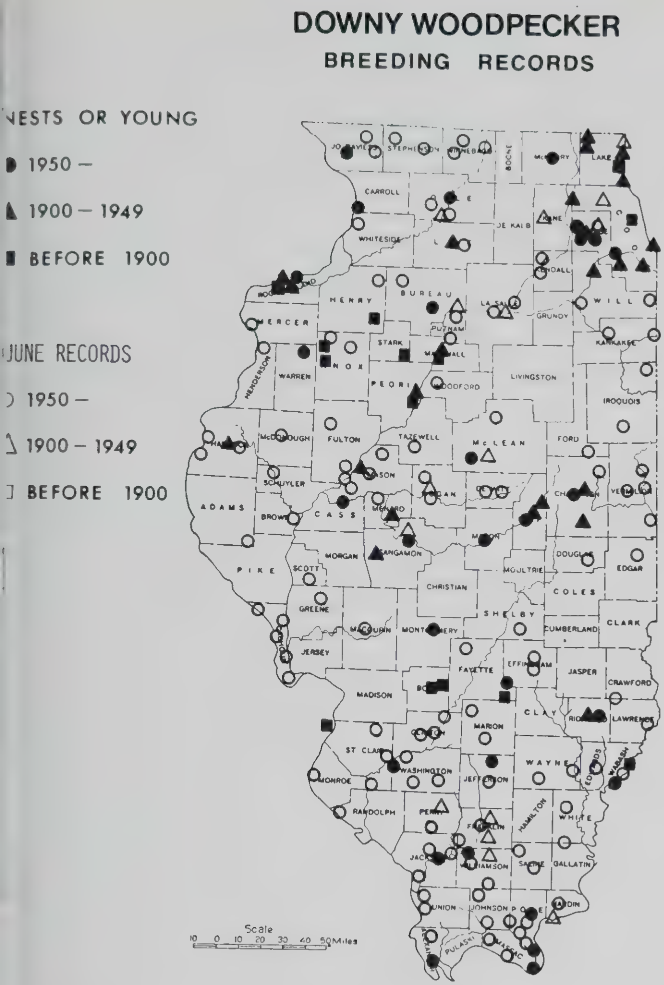


Fig. 47.—Distribution of breeding records of the downy woodpecker in Illinois. Hollow symbols represent birds seen or heard in June.

to nest competition between downies and other species though downies have been seen attacking wrens (Childs 1923).

Fall Populations

In late summer downy woodpeckers become quiet and inconspicuous for a time, probably coincidental with the molt. In northern Illinois we have seen downies about half through the molt in mid-August and early September. George (1972) indicated that the molting period extends into October.

Hulsberg's (1917–1918) statement that downies were coming into town by 1 September is the only observation on the timing of the post-breeding habitat changes of the species. Actually their dispersal probably begins in July and August but may not be apparent in urban areas until later. This dispersal makes the birds more conspicuous, increasing the daily counts (Fig. 46). Our highest counts of downies came consistently in September, as did also those of Swink (1959).

Our spring (March–May) and fall (August–October) counts showed a statewide ratio of 1.0 downy woodpecker in spring to 1.9 in fall, the ratio being highest in the north (1.0:2.1) and lowest in the south (1.0:1.7).

Winter Populations

Downy woodpeckers probably occur in every township in the state in winter, but published records are still lacking for a number of counties (Fig. 48). From population densities we conclude that favorite winter habitats are bottomland forest and shrub habitat, but even corn stubble fields have a fairly consistent, though thin, winter population of downies (Table 18). The downy population in urban areas increases notably in winter over summer levels.

Bottomland woods are an important part of the winter habitat of downy woodpeckers in southern Illinois; over two times as many were found in bottomland as in upland woods. There was a correlation between downy numbers and the Importance of *Ulmus* ($r = 0.613$, $P = < 0.10$). There was a similar degree of correlation for large-tree basal area. The converse was also true—a negative correlation between downies and the basal area of small ($r = -0.638$, $P = < 0.10$) and medium-sized trees ($r = -0.665$, $P = 0.05$). These data indicate an ecological difference between winter and summer downy habitat within the same woodlands, since in summer the correlations were reversed.

In uplands downies seem to choose woodlands with ash trees present ($r = 0.969$, $P = < 0.01$) and to avoid, or at least occur in lesser numbers in, woods with oaks ($r = -0.851$, $P = < 0.05$) or hickories ($r = -0.960$, $P = < 0.01$). This indicates a preference for a more mesic upland forest. There was also a correlation ($r = 0.985$, $P = < 0.001$) between downy numbers and upland forests with high percentages of the basal areas made up of large trees, just as in the bottomlands. There were negative correlations for high basal-area ratios of small and medium-sized trees ($r = -0.872$, $P = < 0.05$; $r = -0.979$, $P = < 0.001$, respectively). There was a correlation between downies and the number of large trees (over 28 inches DBH) per acre in upland woods ($r = 0.942$, $P = < 0.01$). In upland woods there was a positive correlation between the downy and the red-bellied woodpecker ($r = 0.973$, $P = < 0.001$). The diet of these two birds indicates little or no competition between them for food in winter.

From the regional variation in downy woodpecker winter populations, based on the statewide censuses (Graber & Graber 1963), we concluded that there was at least one migratory population of downies in the state. There is still no proof based on the recovery of banded birds that such a migration exists. For the entire state the ratio of summer to winter downy woodpecker numbers was 1.0 (summer) to 1.8 (winter), a slight decline from the fall ratio. Because the fall ratios were roughly similar in all regions of the state, we would expect, lacking migration, that the

Table 17.—Breeding populations of downy woodpeckers in Illinois.

Habitat	Acres	Birds per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Urban residential	160	1	1958	Strip	North	Graber & Graber 1963
Urban residential	173	0	1958	Strip	Central & South	Graber & Graber 1963
Unmodified woodland	27	7	1937	Nest	Lake (N) [b]	Beecher 1942
Oak-maple forest	55	4–22 (avg 13.5)	1927–1943	Map	Champaign (C)	Kendeigh 1944
Oak-maple forest and edge	55	4–48 (avg 16.7)	1944–1975	Map	Champaign (C)	Kendeigh & Forsyth 1959; Kendeigh & Barnett 1967
Oak-maple forest	64	16	1943	Map	Champaign (C)	Johnston 1947
Forest (all types, including edge)	177	2–5 (avg 3.4)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	214	11–13 (avg 12.1)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	60	5–15 (avg 8.3)	1907, 1909	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	340	3–4 (avg 3.5)	1957–1958	Strip	South	Graber & Graber 1963
Mature upland forest	479	1–8 (avg 3.1)	1974–1975	Strip	South	This paper
Mature bottomland forest	1,077	3–26 (avg 9.2)	1973–1975	Strip	South	This paper
Mature bottomland forest	63	16–30 (avg 23.0)	1950–1951	Map	McLean (C)	Calef 1953*a*
Virgin floodplain forest	77	36	1948	Map	Sangamon (C)	Snyder et al. 1948
Virgin floodplain forest	50	20	1947	Map	Piatt (C)	Fawver 1947*b*
Grazed bottomland woods	53	19	1955	Map	Macon (C)	Chaniot & Kirby 1955*b*
Woods, unspecified	20	10–20 (avg 16.7)	1914–1916	Nest	Rock Island (N)	John J. Schafer (unpublished notes 1914–1923)
Woods, unspecified	54	7–11 (avg 8.1)	1917–1923	Nest	Rock Island (N)	John J. Schafer (unpublished notes 1919–1923)
Second-growth hardwoods	15	13–27 (avg 19.9)	1937–1938	Map	Rock Island (N)	Fawks 1937, 1938
Upland second-growth oak-hickory forest	56	4–11 (avg 7.1)	1941–1942, 1944	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*, 1944*b*
Upland second-growth oak-hickory forest	46	13	1948	Map	Sangamon (C)	Robertson & Snyder 1948
Upland oak-hickory	24	8	1967	Map	Hancock (C)	Franks & Martin 1967
Scrub oak-hickory	40	4	1968	Map	Mason (C)	Johnson 1970
Late shrub	21	18	1966	Map	Vermilion (C)	Karr 1968
Shrubby field and forest edge	60	2	1949	Map	Richland (S)	Stine 1949
Shrub areas	39	5	1909	Strip	South	Graber & Graber 1963
Shrub areas	129	2–3 (avg 2.3)	1957–1958	Strip	South	Graber & Graber 1963
Swamp and thicket	13	2	1950	Map	Jackson (S)	Brewer & Hardy 1950
Swampy prairie	64–67	3	1941–1942, 1944	Map	Sangamon (C)	Robertson 1941*a*, 1942*a*, 1944*a*

[a] All figures were converted to birds per 100 acres (territorial males or nests × 2).

[b] N refers to the northern region of Illinois, C to the central, and S to the southern region, as shown on winter distribution maps, e.g., Fig. 5.

winter ratios would also be similar in all regions. However, data from the cross-country censuses indicated that although the winter populations of downies were far above the summer populations in northern and southern Illinois, the population actually declined in winter in central Illinois. A similar pattern is shown in the population data for Trelease Woods (Kendeigh and others 1941–1975) where the long-term average for the downy population is lower in winter than in summer. The resolution of this paradox would seem to require a large-scale banding of downies, especially in central Illinois.

In the past 10 years (1965–1975) the range of annual variation in the Christmas counts of downies was 7–66 percent (average: 28.8) in the north, 2–38 percent (average: 18.2) in central Illinois, and 3–8 percent (average: 29.2) in the south. Aside fro very high peaks between 1915 and 1925 (Fig. 49) the counts show no trend, especially since 1930. Th counts indicate little difference in population densit between the three regions of the state, agreeing i this respect with other types of census data (Tabl 18). On average, a party of observers found on downy about every 45 minutes in central Illinois every 49 minutes in southern Illinois, and one pe 60 minutes in the north.

Food Habits

Zimmer (1921) called the downy woodpecker " suet gourmand," and most of the published reference

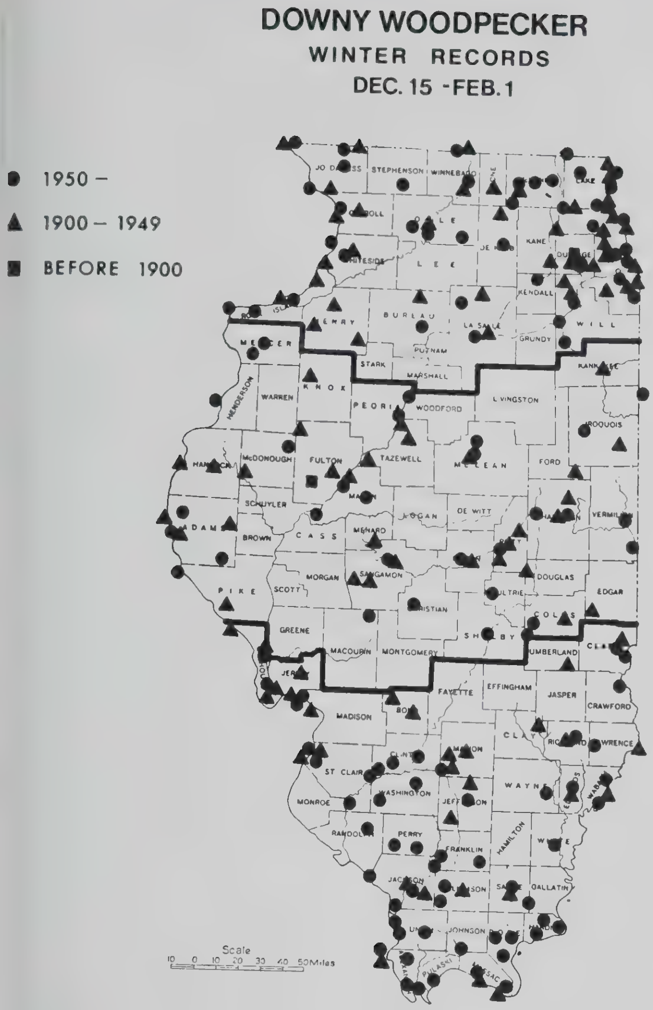


Fig. 48.—Distribution of winter records of the downy woodpecker in Illinois. Heavy horizontal lines separate the three egions (north, central, and south) of the state referred to in he text.

on the food of the downy in Illinois concern its atraction to suet, especially in winter but also at other easons (Brintnall (1918; Schafer 1918; Cone 1956).

The consistent winter population of downies in ields of corn stubble probably reflects the species' redation on corn borers (Moseley 1947; Wall & Whitcomb 1964). Downies also commonly forage on talks of giant ragweed, *Ambrosia trifida,* (Adcock 922; Fawver 1947*a*), but the food item in this case as not been identified. Downies are important predtors on the cocoons of cecropia and other Saturniid noths (Waldbauer et al. 1970).

Rice (1946) found the dominant component of he diet of downies in a Champaign County woods to e beetles and their larvae, which comprise 90 perent of the diet in fall, 80 percent in winter, 70 ercent in spring, and 50 percent in summer.

Beal's (1911) extensive study included some Illiois specimens. He found that animal matter, mainly nsects, made up about 76 percent of the diet, and vegetable matter about 24 percent in the course of a year. Beetles, especially wood-boring cerambycids and buprestids, were the most common food. Ants and caterpillars were also important. A rather surprising dominant food in March specimens from Illinois was grasshopper eggs.

Of the vegetable food, Beal (1911) observed that wild fruits made up about 6 percent of the total, and mast (acorns, beechnuts, etc.) was also important. Some corn was eaten, probably in the form of waste grain. Conspicuous in the diet was the fruit of poison ivy, which germinates freely after passing through the bird, and downies may play a role in spreading this plant.

A measure of the downy's adaptability in foraging is indicated in Southern's (1966) observations of downies feeding on dead gizzard shad in winter and early spring in northwestern Illinois.

Specimen Data

Though two races, *Dendrocopos pubescens medianus* and *D. p. pubescens,* have been ascribed to Illinois (Ridgway 1914; American Ornithologists' Union 1957), we have found no evidence of such geographic variation among the 63 specimens (41 males, 22 females) from Illinois that we have examined. All specimens fell within the probable limits of variation of *medianus.* There was great individual variation in coloration and pattern among downies in contrast to hairy woodpeckers. Tail barring ranged from none (as in *D. villosus*) to heavy, even among specimens from just one county (Will) though specimens with

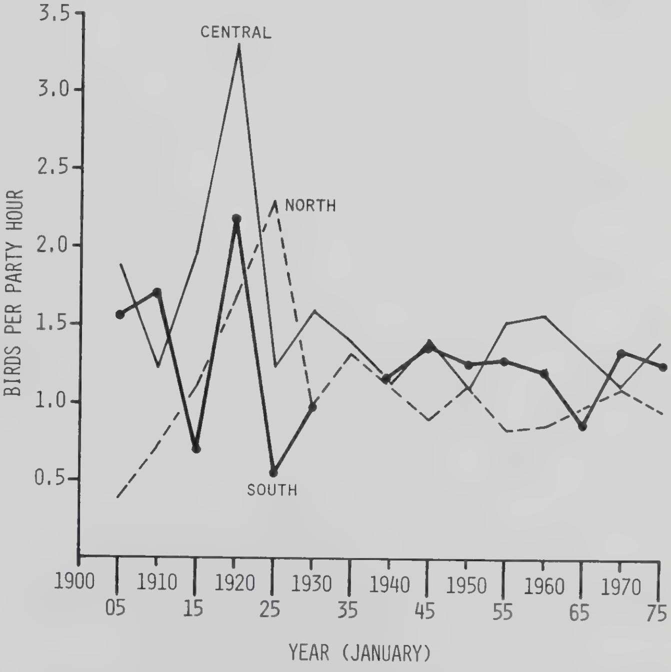


Fig. 49.—Downy woodpeckers seen per party hour on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average.

TABLE 18.—Winter populations of downy woodpeckers in various Illinois habitats.

Habitat	Acres	Birds per 100 Acres	Years (January)	Type of Census	Region or County	Reference
Urban residential	164	0.6	1976	Strip	North	This paper
Urban residential	191	2.6	1976	Strip	Central	This paper
Urban residential	191	3.7	1976	Strip	South	This paper
Suburban woodlot	20	10–15 (avg 12.0)	1968–1972	Map	Lake (N)[a]	Miller & Miller 1968, 1972
Urban park	22	0–5	1960–1962	Map	Cook (N)	Greene 1960; Greene & Greene 1962
Forest (all types, including edge)	46	9–11 (avg 9.8)	1940–1941	Map	Piatt (C)	Johnston 1942
Forest (all types, including edge)	65	9	1907	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	45	4–10 (avg 6.7)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	50	2	1907	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	152	1–7 (avg 4.6)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	241	3	1907	Strip	South	Graber & Graber 1963
Forest (all types, including edge)	211	7–11 (avg 9.0)	1957–1958	Strip	South	Graber & Graber 1963
Oak-maple forest and edge	55	4–35 (avg 12.8)	1944–1975	Map	Champaign (C)	Kendeigh et al. 1957; Kendeigh & Brooks 1964*a*
Bottomland elm-maple forest	50	12–24 (avg 18.5)	1950–1953	Map	Cook (N)	Montague 1950, 1952
Grazed bottomland forest	53	13–19 (avg 16.3)	1955, 1957	Map	Macon (C)	Chaniot & Kirby 1955*a*; Kirby & Chaniot 1957
Mature bottomland forest	1,398	0–35 (avg 13.7)	1974–1976	Strip	South	This paper
Mature upland forest	772	0–17 (avg 5.6)	1974–1976	Strip	South	This paper
Shrub areas (all types, including edge)	18	11	1907	Strip	North	Graber & Graber 1963
Shrub areas (all types, including edge)	74	6–15 (avg 10.8)	1957–1958	Strip	Central	Graber & Graber 1963
Shrub areas (all types, including edge)	33	3	1907	Strip	South	Graber & Graber 1963
Shrub areas (all types, including edge)	101	5–13 (avg 9.9)	1957–1958	Strip	South	Graber & Graber 1963
Shrubby field and forest edge	70	4	1948	Map	Richland (S)	Stine & Scherer 1948
Shrubby field and forest edge	85	4	1955–1956	Map	Richland (S)	Shaw & Stine 1955; Shaw et al. 1956
Shrubby field	40	(+)[b]–7 (avg 4.4)	1958–1965, 1968	Map	Lawrence (S)	Scherer & Shaw 1960; Shaw 1964
Corn stalks and stubble	602	(+)	1907	Strip	North	Graber & Graber 1963
Corn stalks and stubble	308	2	1957	Strip	North	Graber & Graber 1963
Corn stalks and stubble	360	0	1907	Strip	Central	Graber & Graber 1963
Corn stalks and stubble	759	(+)–1 (avg 0.5)	1957–1958	Strip	Central	Graber & Graber 1963
Corn stalks and stubble	282	1–5 (avg 2.1)	1907	Strip	South	Graber & Graber 1963
Corn stalks and stubble	277	0–1 (avg 0.4)	1957–1958	Strip	South	Graber & Graber 1963

[a] N refers to the northern region of Illinois, C to the central region, and S to the southern, as shown on winter distribution maps, e.g., Fig. 5.
[b] The plus symbol (+) indicates fewer than one bird per 100 acres.

TABLE 19.—Measurements of Illinois specimens of downy woodpeckers, excluding obviously worn, molting, and juve nile specimens.

Region of Illinois	Months	Number of Specimens	Sex	Wing (Chord) in mm			Tail Length in mm		
				Range	Mean	SD	Range	Mean	SD
North and Central	Mar.–May	3	M	90–93	91.1	. . .	54–56	55.1	. . .
North and Central	Sep.–Nov.	7	M	89–94	92.0	1.79	54–58	56.2	0.93
North and Central	Dec.–Feb.	8	M	90–98	93.1	2.45	54–58	56.0	1.72
North and Central	Sep.–May	18	M	89–98	92.3	2.09	51–58	55.9	1.34
South	Feb.–Apr.	10	M	89–95	91.8	1.93	51–58	55.3	2.19
North and Central	Sep.–Mar.	9	F	92–95	93.8	1.25	57–61	58.3	1.17
South	Oct.–Mar.	5	F	93–96	94.0	1.47	55–60	57.5	2.04

immaculate rectrices must be rare. Ventral coloration varied from nearly clear white to strong buffy gray, but not in any consistent geographic pattern.

There was no significant difference in size between downies from northern and southern Illinois or between specimens collected in winter, spring, and fall (Table 19). Again, this lack of differences is in contrast to the differences found in the hairy. Female downies, on average, were slightly larger than males, most notably in tail length.

We have weight data on only five specimens, all males. February specimens weighed 24.3 (Menard County), 28.5 (Jersey County), and 29.7 grams (Pope County). A September specimen from Pope County weighed 26.5 grams, and a November specimen from Brown County, 26.5 grams.

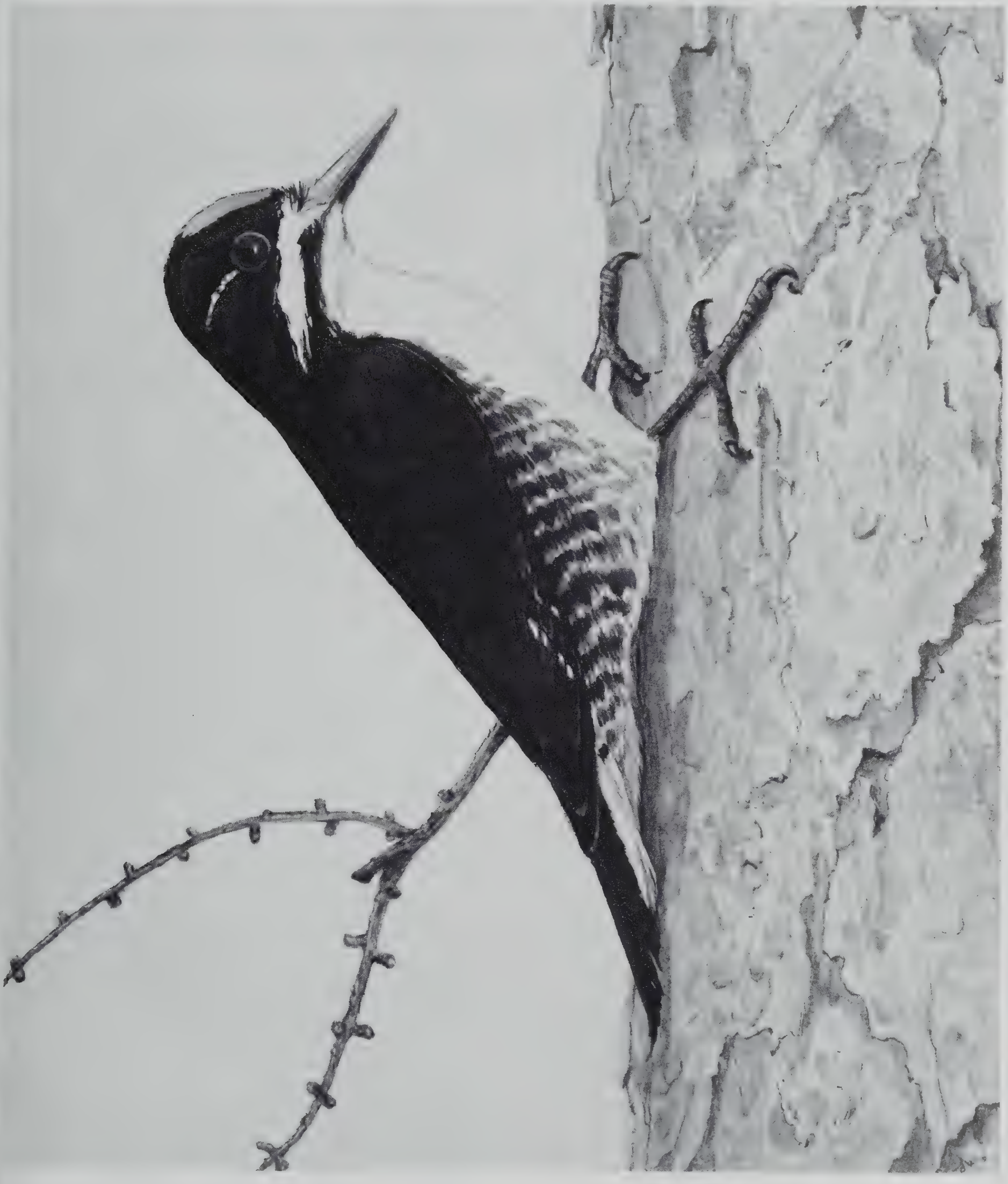


Fig. 50.—Black-backed three-toed woodpecker.

BLACK-BACKED THREE-TOED WOODPECKER *(Picoides arcticus)*

(Fig. 50 and 51)

This northern woodpecker is an uncommon winter visitant of irregular occurrence in northern (particularly northeastern) and central Illinois (Fig. 52). The first record for Illinois was in 1876, when one was found on a telegraph pole in Chicago (Cory 1909).

The black-backed three-toed woodpecker has most often appeared in October and departed in April in the years in which it has been reported; however, the species has been seen as early as 12 September (Redfield 1913) and as late as 19 May (Nolan 1957*b*) in Illinois. The numbers reported each year in Illinois since 1900 are shown in Fig. 53. There are but two records before that time, one in 1876 and another in 1894 (Sanborn 1922*b*). The greatest numbers ever reported for the state were in 1920, reported to have been unusually warm in October and to have had a very mild winter (Eifrig 1921 and 1922). On the other hand, two were reported in Peoria after a severe sleet storm (Starrett 1936).

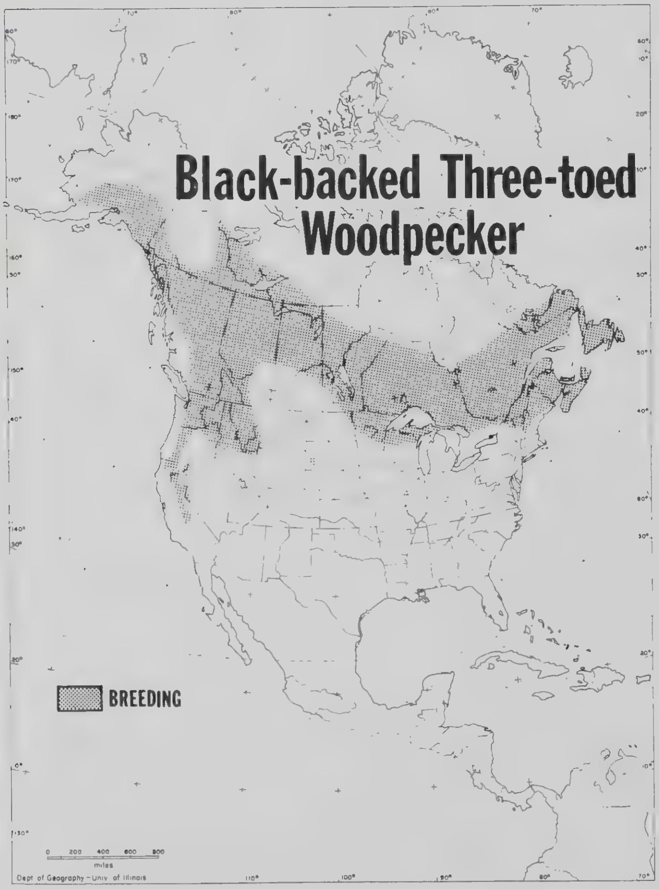

Black-backed Three-toed Woodpecker
BREEDING
miles
Dept of Geography - Univ of Illinois

Fig. 51.—General distribution of the black-backed three-toed woodpecker. The range shown here may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and lack of suitable habitat.

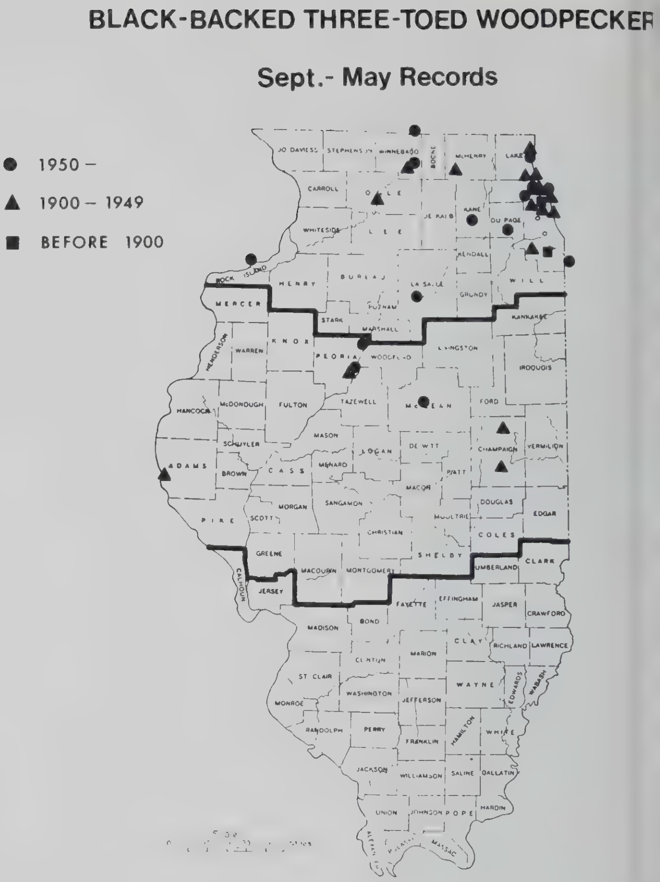


Fig. 52.—Distribution of records of the black-backed three-toed woodpecker in Illinois. Heavy horizontal lines separate the three regions of the state.

Little has been written of the habits of this bird in Illinois. It is usually found singly or, less often with another black-back. It appears to be unwary often allowing observers to approach it closely. It frequently has remained in the same area for some days. It is said to be partial to pines and tamaracks (Stoddard 1920). Stoddard also noted that the black-back had a loud and startling call, a rapidly repeated "teck, teck, teck." Redfield (1913) observed that the pecking of the black-back was audible and distinctive Lewis (1925) and Stoddard (1920) remarked tha the workings of this species on trees were characteristic and could be used to detect its presence. Apparently the bird scales the bark from trees and chisel and bores in quite a distinctive way. There are no data on the food of this species in Illinois, but one was observed at a suet feeder (Mumford 1960). Beal (1911) looked at stomachs from 28 specimens outside of Illinois and found that about 89 percent of the food was animal matter and 11 percent, vegetable matter. Most (64 percent) of the food consisted of wood-boring beetle larvae, and wood-boring caterpillars made up about 13 percent. Beal commented upon the large numbers of destructive grubs that these birds must destroy in a year's time.

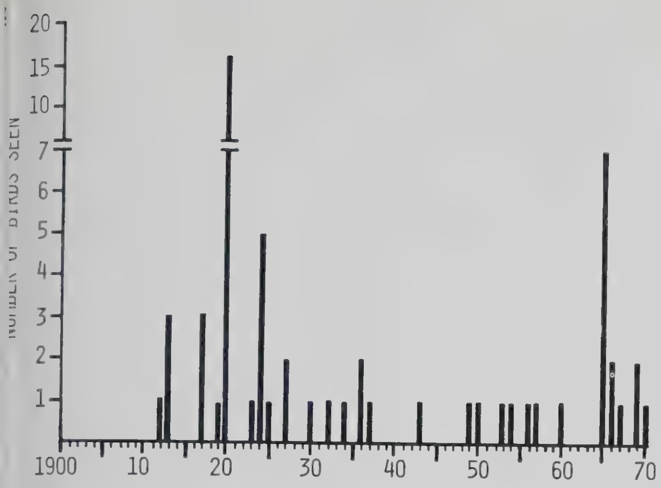


Fig. 53.—Numbers of black-backed three-toed woodpeckers seen yearly in Illinois, with years referring to the beginning of he invasion, e.g., 1920 refers to the winter of 1920–1921. No black-backed three-toed woodpeckers have been reported in Illinois since 1970; however, one was found in Bettendorf, Iowa, in 1975 (Fredricksen 1976).

IVORY-BILLED WOODPECKER
(Campephilus principalis)

There are but three old records and two records of subfossil remains of this species for the state of Illinois. Audubon (1831) saw the ivory-billed woodpecker near the confluence of the Ohio and Mississippi rivers around 1825, and Ridgway thought that he observed it in White County some 40 miles south of Mt. Carmel circa 1852 (Ridgway 1889 and 1914; Tanner 1942). What may have been the last record or the ivory-bill in Illinois is found in the notes of Benjamin T. Gault, who thought that he heard this bird in swamps near Ullin (Pulaski County) on 15 November 1900 (Gault 1922 and unpublished notes). Ridgway (1874*a* and 1874*b*) thought that the ivory-bill was rare among breeding birds in the lower Wabash Valley, and though he spent time in virgin bottomland timber in that area (Ridgway 1872), he made no mention of any contact with the species at hat time.

The habitat of the ivory-billed woodpecker and ts habits were described by Tanner (1942), who tudied the species in Louisiana. The primary habitat of this bird, according to Tanner, was virgin or maure oak-gum bottomland forest, but it also occupied ypress-tupelo forests. The most important trees (to he ivory-bill) in its habitat were sweet gum, bottomand red oak *(Quercus nuttallii)*, green ash, American lm, pecan, "hackberry" *(Celtis laevigata)*, and overup oak. All of these trees or closely related counterparts are found in low-lying forests in southern Illinois, where remnants of mature oak-gum and ypress-tupelo forests remain even now. It is thus asy to believe the records of Audubon, Ridgway, and Gault. These sight records are further reinforced by a specimen from Forest Park, St. Louis, Missouri. This bird, a female, number 27343, was collected on 8 May 1886, and according to Hahn (1963), is in the Colorado Museum of Natural History in Denver.

Subfossil remains were found at Cahokia (near Collinsville, Madison County) and near Milan (Rock Island County) (Parmalee 1967). The tarsometatarsus found in a midden at Cahokia suggests that this bird existed in this area 1000–1200 AD, especially since the presence of suitable habitat existing there at that time is indicated by the discovery of a large trunk section of bald cypress at this site (Parmalee 1968). The mandibles found in a historic Sauk-Fox cemetery near Milan are thought to have been used as personal decoration and may have been obtained from other localities by trade (Parmalee 1964).

This large bird required a large area (one pair per 10 square miles) and a lot of large old trees to supply it with an ample food supply of borers and bark beetles. The ivory-bill disappeared as virgin and mature forests were cut. A portion of its habitat was even destroyed on the Singer tract, a wildlife sanctuary maintained by Louisiana at the time the timber was felled. Tanner's observation that greater numbers of woodpeckers, such as the pileated and red-bellied woodpeckers, occurred in the mature forests also occupied by the ivory-bill suggests that we must take care to preserve older woodlands. The continued clearing of bottomland forests for agricultural use and the harvesting practices on forest land may eventually endanger our largest woodpecker now extant, the pileated.

LITERATURE CITED

Abbott, G. 1897. Large laying capacity of the flicker. Osprey 1 (10) :136.

Adcock, F. 1922. Ecological survey of the fauna of Lake Knox. Illinois State Academy of Science Transactions 15:186–199.

Allison, D. G. 1947. Bird populations of forest and forest edge in central Illinois. M.S. Thesis. University of Illinois. 87 p.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union. 691 p. Baltimore, Maryland.

Anderson, R. A. 1965. Winter survey—December 1 to March 1. Bluebird 32 (1–2) :5–8.

———. 1966. Winter survey—December 1 to February 28. Bluebird 33 (1) :13–16.

———. 1967. Fall survey—August 15 through November 30. Bluebird 34 (1) :7–10.

———. 1971. Spring survey—1972. Bluebird 38 (3) :6–9.

Anderson, R. C. 1970. Prairies in the prairie state. Illinois State Academy of Science Transactions 63 (2) :214–221.

Anderssen, F. G. 1929. Some seasonal changes in the tracheal sap of pear and apricot trees. Plant Physiology 4:459–476.

Anonymous. 1877. Memoranda of eggs collected in 1877. Ornithologist and Oölogist 3 (6) :45.

———. 1916. Spring census and migration records for 1916. Audubon Bulletin, Spring 1916:36–48.

———. 1922. Moline. Audubon Bulletin, Fall 1922:39–41.

———. 1931. Bird banding notes. U.S. Department of Agriculture Biological Survey 2 (3) : 37–38.

———. 1955. Fifty-fifth Christmas bird count. 319. Danville, Ill. Audubon Field Notes 9 (2) :170.

Audubon, J. J. 1831. Ornithological biography. Adam Black, Edinburgh. Vol. 1. 512 p.

Axelson, T., M. Hundley, C. Scherer, V. S. Shaw, and R. Thom, Jr. 1965. Winter bird-population study. 19. Shrubby field and lake. Audubon Field Notes 19 (3) :427.

Baker, F. C. 1936. Remains of animal life from the Kingston kitchen midden site near Peoria, Illinois. Illinois State Academy of Science Transactions 29 (2) :243–246.

Balch, L. 1970. Field notes: two waves of migrants. Audubon Bulletin 156:22.

Barnes, R. M., 1890. List of birds breeding in Marshall Co., Ill. Ornithologist and Oölogist 15 (8) :113–116.

———. 1912. Breeding birds of Marshall Co., Ill. Oölogist 29 (8) :325–328.

Bartel, K. E. 1931. Flickers in a martin house. Oölogist 48 (10) :148.

———. 1959*a*. 1958 station returns of Karl E. Bartel, Blue Island, Illinois. Inland Bird Banding News 31 (4) :37.

———. 1959*b*. The returns. Inland Bird Banding News 31 (6) :58.

———. 1964. Winter bird population trends through banding 1963–64. Winter returning birds 1963–64. Inland Bird Banding News 36 (3) :46–50.

———. 1967. Longevity data from thirty-three years of banding. Inland Bird Banding News 39 (4) :123.

Beal, F. E. L. 1886. Some notes on bird migrations. American Naturalist 20 (9) :817–819.

———. 1911. Food of the woodpeckers of the United States. U.S. Department of Agriculture Biological Survey Bulletin 37. 64 p.

Beall, L. F. 1908. A southern Illinois lunch counter. Bird-Lore 10 (6) :255–257.

Beecher, W. J. 1942. Nesting birds and the vegetation substrate. Chicago Ornithological Society, Chicago. 69 p.

Bellrose, F., Jr. 1934–1935. Winter birds around a feeding station. Audubon Bulletin 24–25:39–42.

Bent, A. C. 1939. Life histories of North American woodpeckers. U.S. National Museum Bulletin 174:1–334.

Black, E. R., Jr., F. M. Davis, C. A. Henderson, and W. A. Douglas. 1970. The role of birds in reducing overwintering populations of the southwestern corn borer, *Diatraea grandiosella* (Lepidoptera: Crambidae), in Mississippi. Entomological Society of America Annals 63 (3) :701–706.

Blake, E. 1948. Winter season—December 1, 1947–March 31, 1948. Middlewestern prairie region. Audubon Field Notes 2 (3) :142–143.

Blake, E. R., and E. T. Smith. 1941. The season, August 1–October 1, 1941. Chicago region. Audubon Magazine 43 (6) :570–572.

Blocher, A. 1927. A summer's record of the automobile. Oölogist 44 (7) :96.

———. 1934. How our birds are doing here. Oölogist 51 (10) : 124–125.

———. 1936*a*. Fatalities. Oölogist 53 (2) :19–22.

———. 1936*b*. Starlings again. Oölogist 53 (12) :166–167.

Bodensten, A. J. 1932. A set of 24 flicker eggs. Oölogist 49 (4) : 45.

———. 1934. Items from Congress Park. Oölogist 51 (4) :48.

———. 1935. Starling and flicker nesting together. Oölogist 52 (11) :132.

Boulton, R., and F. A. Pitelka. 1937. The season. April 15–June 15, 1937. Chicago region. Bird-Lore 39 (4) :319–320.

———, and ———. 1938. The season. August 15–October 15, 1938. Bird-Lore 40 (6) :464–465.

Brewer, R., and J. A. Ellis. 1958. An analysis of migrating birds killed at a television tower in east-central Illinois, September 1955–May 1957. Auk 75 (4) :400–414.

———, and W. Hardy. 1950. 14th breeding bird census. 18. Swamp and thicket. Audubon Field Notes 4 (6) :303.

Brintnall, A. W. 1918. Our summer boarders. Bird-Lore 20 (6) :421–422.

Brodkorb, P. 1928. Flicker trapped by resin. Auk 45 (4) :503–504.

Brown, L. G., and F. C. Bellrose. 1943. Use of nesting boxes for wood ducks by other wildlife. Journal of Wildlife Management 7 (3) :298–306.

Brown, W. H. 1964. Field Reports. Iowa Bird Life 34 (2) :44–49.

Burns, F. L. 1900. A monograph of the flicker (*Colaptes auratus*). Wilson Bulletin 12 (2) :1–82.

Bush, L. 1934–1935. Winter notes from Williamson County. Audubon Bulletin 24–25:51–52.

Butcher, H. C. 1896. The murderous woodpecker. Osprey 1 (2) : 27.

Butler, A. W. 1897. Birds of Indiana. Pages 515–1187 in 22nd annual report of the Department of Geology and Natural Resources of Indiana for 1897. [Indiana Academy of Science Proceedings for 1908.]

Cahn, A. R., and A. S. Hyde. 1929. Easter birds of Little Egypt. Wilson Bulletin 41 (1) :31–38.

Calef, R. T. 1953*a*. Ecological analysis of the flora and vertebrate fauna of Funks Forest Natural Area, McLean Co., Ill. 85 p. M. S. Thesis. University of Illinois.

———. 1953*b*. Avian populations of the Funk Forest Natural Area in McLean County, Illinois. Illinois State Academy of Science Transactions 46:240–257.

Chaniot, G., and R. Kirby. 1955*a*. Winter bird population study. 27. Grazed stream bottomland. Audubon Field Notes 9 (3) :303.

———, and ———. 1955*b*. Nineteenth breeding-bird census. 4. Grazed stream bottomland. Audubon Field Notes 9 (6) :413.

———, and ———. 1956. Winter bird-population study. 23. Grazed stream bottomland. Audubon Field Notes 10 (3) : 296–297.

Childs, N. I. 1922. Suet basket. Audubon Bulletin, Spring 1922:12.

———. 1923. Bird notes. Audubon Bulletin, Spring 1923:24.

Coffin, E. L. 1970. Is a flicker fascinated in some way by a sparrow hawk? Audubon Bulletin 154:12.

Comfort, J. E. 1940. Webster groves. Bluebird 7 (11) :72.

———. 1949. Review of 1948. Bluebird 16 (1) :n.p.

Cone, B. 1956. Half a ton of cheese. Audubon Bulletin 97:4–5.

Cooke, M. T. 1937. Some returns of banded birds. Bird Banding 8 (4) :144–155.

———. 1943. Returns from banded birds: some miscellaneou recoveries of interest. Bird Banding 14 (3) :67–74.

———. 1946. Returns of banded birds: some recent records o interest. Bird Banding 17 (2) :63–71.

———. 1950. Returns from banded birds. Bird Banding 21 (1) 11–18.

Cooke, W. W. 1885*a*. Mississippi Valley migration. Ornithologist and Oölogist 10 (10) :145–147.

———. 1885*b*. Bird migration in the Mississippi Valley. Winter birds of southern Illinois. Forest and Stream 23 (23) 444–445.

———. 1888. Report on bird migration in the Mississippi valle in the years 1884 and 1885. U.S. Department of Agricultur Division of Economic Ornithology Bulletin 2. 313 p.

———. 1916. Second annual report of bird counts in th United States, with discussion of results. U.S. Departmen of Agriculture Bulletin 396. 20 p.

———, and O. Widmann. 1884. Bird migration in the Mississippi Valley. American Field 21 (4) :88–89.

Cory, C. B. 1909. The birds of Illinois and Wisconsin. Fiel Museum of Natural History Publication 131, Zoologica Series 9. 766 p.

Coursen, C. B. 1941. [Untitled note.] Inland Bird Bandin News 13 (2) :18.

———. 1947. Birds of the Orland Wildlife Refuge. Turto News (Supplement). 30 p.

Craigmile, E. 1945. Bird walks in Thatcher's woods. Audubo Bulletin 54: 3–7.

Cunningham, J. W. 1948. Winter season. December 1, 1947 t March 31, 1948. Missouri region. Audubon Field Not 2 (3) : 144.

Donovan, M. 1934. An experience with birds. Chicago Academ of Sciences Program of Activities 5 (4) :90.

Dorsey, G. A. 1925. Woodpeckers in cornfields. Bird-Lore 2 399.

Du Bois, A. D. 1918. An annotated list of the birds observe from May to July in central Logan County, Illinois. Oöl gist 35 (11) :143–146.

DuMont, P. A. 1936. Old nesting records of rare birds in Iowa. Oölogist 53 (1) :8–10.

———. 1947*a*. Winter season. Dec. 1, 1946–April 1, 1947. Middle-western region. Audubon Field Notes 1 (3) :129–131.

———. 1947*b*. Spring migration April 1 to June 1, 1947. Middle-western region. Audubon Field Notes 1 (4) :154–156.

Duncan, D. 1937. Winter birds of Park Ridge. Audubon Bulletin 27:21–23.

Eaton, D. H. 1878. List of birds in Peotone and vicinity. Forest and Stream 11 (3) :47.

E. E. 1885. English sparrows (what is to be done with the little tyrants?) The Young Oölogist 1 (11) :146.

Egan, W. C. 1923. The flickers' dance. Audubon Bulletin, Fall 1923:39.

Eifrig, G. 1921. Unusual winter occurrences at Chicago. Auk 38 (4) :609–610.

———. 1922. A mild winter and its effect on the migration of birds at Chicago. Wilson Bulletin 34 (2) :90–94.

———. 1930*a*. Fluctuations in the numerical status of birds. Chicago Academy of Sciences Program of Activities 1 (4) : n.p.

———. 1930*b*. Nesting of the starling in the Chicago region and other notes of 1929. Audubon Bulletin 20:9–10.

———. 1931. Some 1929 bird notes from the Chicago region. Wilson Bulletin 43 (1) :62–63.

———. 1937. The changing status of birds as regards their abundance. Illinois State Academy of Science Transactions 30 (2) :295–297.

———. 1938. The changing status of birds in regard to their abundance. Audubon Bulletin 28:21–24.

Eisenmann, E. 1973. Thirty-second supplement to the American Ornithologists' Union check-list of North American Birds. Auk 90 (2) :411–419.

Ekblaw, W. E. 1919. Birds from a sick man's window. Wilson Bulletin 31 (3) :91–97.

Fawks, E. 1937. Bird-lore's first breeding-bird census. Second growth hardwood. Bird-Lore 39 (5) : 380–381.

———. 1938. Bird-lore's second breeding-bird census. Second growth hardwood. Bird-Lore 40 (5) : 359.

———. 1966. Field notes—March 1966. Audubon Bulletin 137:3–5.

———. 1967. Field notes. Audubon Bulletin 143:17–21.

———. 1970. Field notes. Audubon Bulletin 154:13.

Fawver, B. J. 1947*a*. The bird and mammal population of an Illinois flood plain forest. M. S. Thesis. University of Illinois. 51 p.

———. 1947*b*. Bird population of an Illinois flood plain forest. Illinois Academy of Science Transactions 40:178–189.

Ferry, J. F. 1907*a*. Winter bird notes from extreme southern Illinois. Auk 24 (3) :281–286.

———. 1907*b*. Further notes from extreme southern Illinois. Auk 24 (4) :430–435.

Field, N. W. 1917. War in the air. Oölogist 34 (6) :113.

Flint, W. P. 1926. The automobile and wildlife. Science 63 (1634) :426–427.

———. 1934–1935. The automobile and wildlife. Illinois State Academy of Science Transactions 27 (2) :150–153.

Forbes, S. A. 1881. The ornithological balance-wheel. Illinois Horticultural Society Transactions 26: 120–131.

———. 1882*a*. The regulative action of birds upon insect oscillations. Illinois State Laboratory of Natural History Bulletin 1 (6) : 3–32.

———. 1882*b*. Notes on economic ornithology. Illinois State Horticultural Society Transactions 27:60–71.

Ford, E. R. 1933. Bird house survey in winter. Audubon Bulletin 23:44–45.

———. 1939. Bird houses. Chicago Academy of Sciences Leaflet 3. n.p.

———. 1956. Birds of the Chicago region. Chicago Academy of Sciences Special Publication 12. 117 p.

———, C. C. Sanborn, and C. B. Coursen. 1934. Birds of the Chicago region. Chicago Academy of Sciences Program of Activities 5 (2–3) :17–76.

Franks, E. C., and W. Martin. 1967. Thirty-first breeding-bird census. 6. Upland oak-hickory forest. Audubon Field Notes 21 (6) :615.

Fredricksen, M. 1976. Northern three-toed woodpecker in Iowa. Iowa Bird Life 46 (1) :27.

Gates, F. C. 1911. Summer bird life in the vicinity of Havana, Illinois in its relation to the prominent plant associations. Wilson Bulletin 23 (1) :1–27.

Gault, B. T. 1901. June and July, bird-life at Glen Ellyn (near Chicago) Illinois. Bird-Lore 3 (3) :102–104.

———. [1922.] Check list of the birds of Illinois. Illinois Audubon Society, Chicago. 80 p.

———. 1932. The saw-whet owl at Glen Ellyn. Audubon Bulletin 22:60.

George, W. G. 1968. Check list of birds of southern Illinois, 1968. Mimeographed. Southern Illinois University, Carbondale. 28 p.

———. 1972. Age determination of hairy and downy woodpeckers in eastern North America. Bird-Banding 43 (2) :128–135.

Goelitz, W. A. 1915. Notes from the Waukegan, Ill., flats. Oölogist 32 (8) :133–134.

———. 1917. 1916 list of Illinois nests. Oölogist 34 (5) :87.

Gower, C. 1933. Horse-shoe Lake. Audubon Bulletin 23:31–33.

Graber, J. W., and R. R. Graber. 1976. Environmental evaluations using birds and their habitats. Illinois Natural History Survey Biological Notes 97. 40 p.

Graber, R. R. 1962. Regional reports. Fall migration August 16–November 30, 1961. Middlewestern prairie region. Audubon Field Notes 16 (1) :35–37, 41–43.

———. 1968. Nocturnal migration in Illinois—different points of view. Wilson Bulletin 80 (1) :36–71.

———, and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906–1909 and 1956–1958. Illinois Natural History Survey Bulletin 28 (3) :383–528.

———, ———, and E. L. Kirk. 1970. Illinois birds: Mimidae. Illinois Natural History Survey Biological Notes 68. 38 p.

Greene, S. H. 1960. Winter bird-population study. 18. City park, lagoon, harbor, and lake. Audubon Field Notes 14 (3) : 352–353.

———, and R. H. Greene. 1962. Winter bird-population study. 18. City park, lagoon, harbor, and lake. Audubon Field Notes 16 (3) :374.

Gross, A. O., and S. A. Forbes. 1909. The economic values of some common Illinois birds. Illinois Department of Public Instruction Arbor and Bird Day Circular: 53–74.

Hahn, P. 1963. Where is that vanished bird?: an index to the known specimens of the extinct and near extinct North American species. Royal Ontario Museum, University of Toronto. 347 p.

Hamilton, J. L. 1969. Spring survey. Bluebird 36 (1) :26–28.

Hammond, V. F. 1934–1935. Our bird house. Audubon Bulletin 24–25:62.

Hankinson, T. L. 1915. The vertebrate life of certain prairie and forest regions near Charleston, Illinois. Illinois State Laboratory of Natural History Bulletin 11 (3) :281–303.

Havera, S. P., C. M. Nixon, and F. I. Collins. 1976. Fox squirrels feeding on buckeye pith. American Midland Naturalist 95 (2) :462–464.

Hess, I. E. 1904. Hairy woodpecker in Illinois. Oölogist 21 (4) : 59.

———. 1910. One hundred breeding birds of an Illinois ten-mile radius. Auk 27 (1) :19–32.

Hine, A. 1924. Lewis's woodpecker visits Chicago. Auk 41 (1) : 156–157.

Holcombe, C. E. 1931. Helping the flicker. Inland Bird Banding News 3 (3) :11–12.

———. 1938. Illinois. Inland Bird Banding News 10 (3) :8.

Holland, H. M. 1931. Doves and woodpeckers. Oölogist 48 (5) : 61–62.

Howell, A. H. 1910. Breeding records for southern Illinois. Auk 27 (2) :216.

Hoyt, J. S. Y. 1941. Through the year with the pileated woodpecker. Audubon Magazine 43:525–528.

———. 1944. Preliminary notes on the development of nestling pileated woodpeckers. Auk 61 (3) :376–384.

Hoyt, S. F. 1957. The ecology of the pileated woodpecker. Ecology 38 (2) :246–256.

Hulsberg, E. 1917–1918. Notes from La Grange. Audubon Bulletin, Winter 1918–1919:31.

Hundley, M., W. Bridges, C. Scherer, and V. S. Shaw. 1956. Winter bird-population study. 25. Shrubby field and forest edge. Audubon Field Notes 10 (3) :297.

Hurter, J. 1884. List of birds. Ornithologist and Oölogist 9 (8) :95–97.

Jackson, A. W. 1919. Bird songs. Illinois State Academy of Science Transactions 12:166–179.

Johnson, R. W. 1936. Bird migration at Dubuque. Iowa Bird Life 6 (1) :8–9.

———. 1941. Notes from Dubuque. Iowa Bird Life 11 (1) :15.

Johnson, W. W. 1970. The resident mammal and bird populations of a sand prairie and forest near Bath, Illinois. Illinois State Academy of Science Transactions 63 (3) :234–239.

Johnston, V. R. 1942. Factors influencing local movements of woodland birds in winter. Wilson Bulletin 54 (3) :192–198.

———. 1944. Observations on the courtship of four woodland birds. Auk 61 (3) :478–480.

———. 1947. Breeding birds of the forest edge in Illinois. Condor 49 (2) :45–53.

Jones, S. 1933. The season. St. Louis region. Bird-Lore 35 (6) : 332–334.

———. 1934. St. Louis region. Bird-Lore 36 (4) :247–248.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70 (4) :348–357.

Kendeigh, S. C. 1941. Distribution of upland birds in Illinois. Illinois State Academy of Science Transactions 34 (2) :225–226.

———. 1944. Measurement of bird populations. Ecological Monographs 14 (1) :67–106.

———. 1948*a*. Winter bird-population study. 1. Oak-maple forest and forest edge. Audubon Field Notes 2 (3) :151–152.

———. 1948*b*. Twelfth breeding-bird census. 10. Oak-maple forest and edge. Audubon Field Notes 2 (6) :232–233.

———. 1949. Winter bird-population study. 9. Oak-maple forest and forest edge. Audubon Field Notes 3 (3) :191.

———. 1960*a*. Winter bird-population study. 19. Oak-maple forest and forest edge. Audubon Field Notes 14 (3) :353.

———. 1960*b*. 24th breeding bird census. 29. Oak-maple forest and edge. Audubon Field Notes 14 (6) :502.

———. 1973. 26th winter bird-population study. 16. Oak-maple forest and forest edge. American Birds 27 (3) :675.

———, and L. B. Barnett. 1967. Thirty-first breeding-bird census. 38. Oak-maple forest and edge. Audubon Field Notes 21 (6) :639.

———, and R. D. Brewer. 1956. Twentieth breeding-bird census. 36. Oak-maple forest and forest edge. Audubon Field Notes 10 (6) :434.

———, and W. S. Brooks. 1962. Winter bird-population study. 9. Oak-maple forest and forest edge. Audubon Field Notes 16 (3) :370–371.

———, and ———. 1963*a*. Winter bird-population study. 9. Oak-maple forest and forest edge. Audubon Field Notes 17 (3) :367.

———, and ———. 1963*b*. 27th breeding-bird census. 36. Oak-maple forest and edge. Audubon Field Notes 17 (6) : 510.

———, and ———. 1964*a*. Winter bird-population study. 11. Oak-maple forest and forest edge. Audubon Field Notes 18 (3) :395.

———, and ———. 1964*b*. Twenty-eighth breeding-bird census. 25. Oak-maple forest and edge. Audubon Field Notes 18 (6) : 557–560.

———, and ———. 1965. Twenty-ninth breeding-bird census. 24. Oak-maple forest and edge. Audubon Field Notes 19 (6) :603.

———, and R. J. Clemans. 1970. Winter bird-population study. 13. Oak-maple forest and forest edge. Audubon Field Notes 24 (3) :548.

———, and J. M. Edgington. 1974. Thirty-eighth breeding bird census. 38. Oak-maple forest and edge. American Birds 28 (6) :1006–1007.

———, and N. J. Forsyth. 1959. Twenty-third breeding bird census. 27. Oak-maple forest and edge. Audubon Field Notes 13 (6) :472-473.

———, and W. Gillespie. 1955. 19th breeding bird census. 38. Oak-maple forest and forest-edge. Audubon Field Notes 9 (6) :431.

———, D. James, and C. Weise. 1953. Winter bird population study. 20. Oak-maple forest and forest edge. Audubon Field Notes 7 (3) :245.

———, R. V. Kennedy, G. C. West, W. I. Gillespie, and J. Opsahl. 1957. Winter bird-population study. 17. Oak-maple forest and forest edge. Audubon Field Notes 11 (3) : 301.

———, R. K. Stubbs, and D. James. 1951. Winter bird-population study. 18. Oak-maple forest and forest edge. Audubon Field Notes 5 (3) :237–238.

Kennicott, R. 1853–1854. Catalogue of animals observed in Cook County. Illinois State Agricultural Society Transactions 1:577–595.

Kilham, L. 1958. Pair formation, mutual tapping and nest hole selection of red-bellied woodpeckers. Auk 75 (3) :318–329.

———. 1959. Behavior and methods of communication of pileated woodpeckers. Condor 61 (6) :377–387.

———. 1961. Reproductive behavior of red-bellied woodpeckers. Wilson Bulletin 73 (3) :237–254.

———. 1964. The relations of breeding yellow-bellied sapsuckers to wounded birches and other trees. Auk 81 (4) : 520–527.

King, D. B., and R. K. Winters. 1952. Forest resources and industries of Illinois. University of Illinois Agricultural Experiment Station Bulletin 562. 95 p.

Kinney, D. F. 1868. Report on birds. Transactions of the Illinois State Agricultural Society 6:371.

Kirby, R., and J. Chaniot, Jr. 1957. Winter bird population study. 16. Grazed stream bottomland. Audubon Field Notes 11 (3) :301.

Kleen, V. M., and L. Bush. 1971. Spring migration. Middlewestern prairie region. American Birds 25 (4) :750–753.

Knable, A. E. 1970. Food habits of the red fox *(Vulpes fulva)* in Union County, Illinois. Illinois State Academy of Science Transactions 63 (4) :359–365.

Komarek, C. V., and E. G. Wright. 1929. Bird casualties on the highways. Wilson Bulletin 41 (2) :106.

Kramer, C. H. 1959. Fifty-ninth Christmas bird count. 349. Princeton, Ill. Audubon Field Notes 13 (2) :188–189.

Kumlien, L., and N. Hollister. 1951. The birds of Wisconsin. Revised ed. Wisconsin Society for Ornithology, Madison. 122 p.

Kyler, J. F. 1927. Bob, the redhead. Bird-Lore 29 (5) :335–338.

Labahn, F. C., Jr. 1941. Banding at Blue Island, Illinois. Inland Bird Banding News 13 (2) :17–18.

Labisky, R. F., and S. H. Mann. 1961. Observation of avian pox in a yellow-shafted flicker. Auk 78 (4) :642.

Lampert, C. 1922. Bird notes. Audubon Bulletin, Fall:32–33.

Lawrence, L. de K. 1967. A comparative life-history study of four species of woodpeckers. Ornithological Monograph 5. American Ornithologists' Union. 156 p.

Le Baron, W. 1855. Observation upon some of the birds of Illinois most interesting to the agriculturist. Transactions of the Illinois State Agricultural Society for 1853, 1:559–565.

Lewis, G. P. 1925. The season. Chicago region. Bird-Lore 27 (2) :118–119.

Lincoln, F. C. 1924. Returns from banded birds. 1920–1923. U.S. Department of Agriculture Bulletin 1268. 53 p.

———. 1927. Returns from banded birds. U.S. Department of Agriculture Technical Bulletin 32. 95 p.

———. 1939. The migration of American birds. Doubleday Doran and Company, Inc., New York. 189 p.

Lindsey, A. A., J. D. Barton, Jr., and S. R. Miles. 1958. Field efficiencies of forest sampling methods. Ecology 39 (3) :428–444.

Link, G. M. 1940. Many birds are here in winter. Bluebird 7 (3) :23–24.

———. 1945. Key to Illinois birds' nests. Audubon Bulletin 54:9–11.

Loucks, W. E. 1891. List of birds found breeding in the vicinity of Peoria, Illinois. Oölogist 8 (11) :224–226.

Lyon, W. I. 1921*a*. Bird-banding at Waukegan. Audubon Bulletin, Spring 1921:16–20.

———. 1921*b*. Notes from the field, revised to March 15, 1921. Audubon Bulletin, Spring 1921:42.

———. 1922. Owl kidnaps young flickers. Wilson Bulletin 34 (4) :230–231.

———. 1923. Bird banding department. Wilson Bulletin 35 (2) : 106–108.

———. 1925. Bird banding news—miscellaneous notes. Wilson Bulletin 37 (3) :182.

———. 1930. The mid-winter survey. Audubon Bulletin 20: 31–32.

———. 1934. Illinois. Inland Bird Banding News 6 (4) :5.

———. 1934–1935. Banding events of 1934. Audubon Bulletin 24–25:42–43.

Mayfield, H. 1951. Winter season. December 1, 1950–March 31, 1951. Middle-western prairie region. Audubon Field Notes 5 (3) :207–208.

McAtee, W. L. 1911. Woodpeckers in relation to trees and wood products. U.S. Biological Survey Bulletin 39:1–99.

Mengel, R. M. 1965. The birds of Kentucky. American Ornithologists' Union Ornithological Monographs 3. 581 p.

Miller, D. E., and W. B. Miller. 1968. Winter-bird population study. 25. Suburban woodlot. Audubon Field Notes 22 (3) : 491–492.

———, and ———. 1970. Winter bird-population study. 27. Suburban woodlot. Audubon Field Notes 24 (3) :558.

———, and ———. 1972. Winter bird-population study. 54. Suburban woodlot. American Birds 26 (3) :686–687.

Montague, A. C. 1950. Winter bird-population study. 12. Bottomland deciduous forest. Audubon Field Notes 4 (3) :225–226.

———. 1951. Winter bird-population study. 19. Bottomland deciduous forest. Audubon Field Notes 5 (3) :238.

———. 1952. Winter bird-population study. 27. Bottomland deciduous forest. Audubon Field Notes 6 (3) :227.

———. 1953. Winter bird-population study. 21. Bottomland deciduous forest. Audubon Field Notes 7 (3) :246.

Montgomery, A. E. 1956. Bird mortality in Elmhurst. Audubon Bulletin 99:1–3.

Mooney, J. 1932. Notes on bird life in Lake County. Audubon Bulletin 22:57–59.

Moseley, E. L. 1947. Variations in the bird population of the north-central states due to climatic and other changes. Auk 64 (1) :15–35.

Moseley, M. L. 1917. Czar red-head. Audubon Bulletin, Spring 1917:18.

Mumford, R. E. 1959*a*. Fall migration. August 16–November 30, 1958. Middlewestern region. Audubon Field Notes 13 (1) : 33–37.

———. 1959*b*. Winter season. December 1, 1958–March 31, 1959. Middlewestern prairie region. Audubon Field Notes 13 (3) :295–298.

———. 1960. Winter season. December 1, 1959–March 31, 1960. Middlewestern prairie region. Audubon Field Notes 14 (3) : 312–314.

———. 1961. Regional reports. Nesting season. June 1 to August 15, 1961. Middlewestern prairie region. Audubon Field Notes 15 (5) :471–472.

Musselman, T. E. 1913. A comparative study of bird migration in Illinois along the 40th parallel of latitude. M. A. Thesis, University of Illinois. 74 p.

———. 1916. Spring census and migration records for 1916. Audubon Bulletin, Spring 1916:42.

———. 1916–1917. Unusual birds along the Mississippi River near Quincy. Audubon Bulletin, Winter 1916–1917:39–40.

———. 1926. Quincy district, the eagles at Warsaw. Audubon Bulletin 17:41–42.

———. 1930. Report for central western Illinois. Audubon Bulletin 20:20–22.

———. 1931. The 1930 season at Quincy. Audubon Bulletin 21:29–31.

———. 1932. The 1931 season at Quincy. Audubon Bulletin 22:48–51.

———. 1933. Quincy nature diary for 1932. Audubon Bulletin 23:50–54.

———. 1934. The value of project work in bird banding. Inland Bird Banding News 6 (2) :11–13.

———. 1934–1935. 1934 nature diary. Audubon Bulletin 24–25:27–35.

———. 1935. Three years of eastern bluebird banding and study. Bird-banding 6 (4) :117–125.

———. 1937. 1936 nature diary. Audubon Bulletin 27:36–44.

Nelson, E. W. 1876–1877. Birds of north-eastern Illinois. Essex Institute Bulletin 8 (9–12) :90–155.

———. 1877. Notes upon birds observed in southern Illinois between July 17 and September 4, 1875. Essex Institute Bulletin 9:32–65.

Nolan, V., Jr. 1955. The nesting season. June 1–August 15, 1955. Middlewestern prairie region. Audubon Field Notes 9 (5) :380–382.

———. 1957*a*. Fall migration. August 16–November 30, 1956. Middlewestern prairie region. Audubon Field Notes 11 (1) : 28–30.

———. 1957*b*. Spring migration. April 1–May 31, 1957. Middlewestern prairie region. Audubon Field Notes 11 (4) : 348–350.

———. 1958. Spring migration. Middlewestern prairie region. Audubon Field Notes 12 (4) :356–358.

Noyes, M. J. S., and F. C. Hill. 1974. Faunal remains from a Lewis focus stone fort in southern Illinois. Illinois State Academy of Science Transactions 67 (3) :336–338.

Oberholser, H. C. 1928. The migration of North American birds. Bird-Lore 30 (3) :253–257.

Parmalee, P. W. 1959. Animal remains from the Modoc Rock shelter site, Randolph County, Illinois. Illinois State Museum Report of Investigations 8:61–65.

———. 1962. Additional faunal records from the Kingston Lake site, Illinois. Illinois State Academy of Science Transactions 55 (1) :6–12.

———. 1964. Vertebrate remains from an historic archaeological site in Rock Island County, Illinois. Illinois State Academy of Science Transactions 57 (3) :167–174.

———. 1967. Additional noteworthy records of birds from archaeological sites. Wilson Bulletin 70 (3) :155–162.

———. 1968. Cave and archaeological faunal deposits as indicators of post-Pleistocene animal populations and distribution in Illinois. The Quaternary in Illinois. University of Illinois College of Agriculture Special Publication 14:104–113.

———. 1969. Animal remains from the archaic Riverton, Swan Island and Robeson Hill sites, Illinois. Illinois State Museum Reports of Investigations 13:139–144.

Patterson, A. J. 1923. [Bird notes.] Audubon Bulletin, Spring 1923:31.

Petersen, P. C., Jr. 1956. Unusual records from Tri-cities. Audubon Bulletin 98:15–16.

———. 1959. TV tower mortality in western Illinois. Audubon Bulletin 112:14–15.

———. 1964. Regional reports. Winter season December 1, 1963–March 31, 1964. Middlewestern prairie region. Audubon Field Notes 18 (3) :359–360.

———. 1966. Regional reports. Winter season December 1, 1965–March 31, 1966. Middlewestern prairie region. Audubon Field Notes 20 (3) :429–431.

———. 1967. Regional reports. Winter season. December 1, 1966–March 31, 1967. Middlewestern prairie region. Audubon Field Notes 21 (3) :424–426.

Polder, E. 1963. Starling and woodpecker interactions. Iowa Bird Life 33 (2) :42–43.

Redfield, R., Jr. 1913. The arctic three-toed woodpecker in Illinois. Bird-Lore 15 (6) :368.

Reller, A. W. 1972. Aspects of behavioral ecology of red-headed and red-bellied woodpeckers. American Midland Naturalist 88 (2) :270–290.

Remington, C. L. 1944. Banding at Principia College, Elsah, Illinois. Inland Bird Banding News 16 (3) :21.

Reuss, A. 1963. Unusuals sighted. Audubon Bulletin 128:23.

Rice, L. A. 1946. Studies on deciduous forest animal populations during a two-year period with differences in rainfall. American Midland Naturalist 35 (1) :153–171.

Ridgway, J. E. 1923. Olney. Audubon Bulletin, Spring 1923: 32–36.

Ridgway, R. 1872. Notes on the vegetation of the lower Wabash Valley. American Midland Naturalist 6:658–665, 724–732.

———. 1874*a*. The lower Wabash valley, considered in its relation to faunal districts of the eastern region of North America. Boston Society of Natural History Proceedings 16:304–332.

———. 1874*b*. Catalogue of the birds ascertained to occur in Illinois. Lyceum of Natural History of New York Annals 10:364–394.

———. 1881*a*. An unaccountable migration of the red-headed woodpecker. Nuttall Ornithological Club Bulletin 6 (2): 120–122.

———. 1881*b*. A revised catalogue of the birds ascertained to occur in Illinois. Illinois State Laboratory of Natural History Bulletin 1 (4) :163–208.

———. 1887. List of birds found breeding within corporate limits of Mt. Carmel, Illinois. Ridgway Ornithological Club Bulletin 2:26–35.

———. 1889. The ornithology of Illinois. Vol. 1. Illinois State Laboratory of Natural History. Reprinted 1913, Pantagraph Printing and Stationery Company, Bloomington, Ill. 520 p. + 32 plates.

———. 1914. Birds of Middle and North America. U.S. National Museum Bulletin 50, Part 6. 882 p. + 26 plates.

———. 1915. Bird life in southern Illinois. IV. Changes which have taken place in half a century. Bird-Lore 17 (3) :191–198.

———. 1920. Notes from Bird Haven, Olney, Illinois. Audubon Bulletin, Fall 1920:20.

Roberts, G. 1922. Seven years of a food shelf. Audubon Bulletin, Spring 1922:7–9.

Robertson, W., Jr.. 1941*a*. Audubon magazine's fifth breeding-bird census. 9. Swampy prairie. Audubon Magazine 43 (5) : 485.

———. 1941*b*. Audubon Magazine's fifth breeding-bird census. 33. Cut-over upland forest with pond. Audubon Magazine 43 (5) :496–497.

———. 1942*a*. Audubon magazine's sixth breeding-bird census. 5. Swampy prairie. Audubon Magazine 44 (5) :18–19 (Supplement) .

———. 1942*b*. Audubon Magazine's sixth breeding-bird census. 22. Cut-over upland oak-hickory forest with pond. Audubon Magazine 44 (5) :27 (Supplement) .

———. 1944*a*. Audubon magazine's eighth breeding-bird census. 5. Swampy prairie. Audubon Magazine 46 (5) :16 (Supplement) .

———. 1944*b*. Audubon magazine's eighth breeding-bird census. 14. Upland oak-hickory forest with pond. Audubon Magazine 46 (5) :19 (Supplement) .

Robertson, W. B., and D. Snyder. 1948. Twelfth breeding-bird census. 11. Cut-over upland oak-hickory forest. Audubon Field Notes 2 (6) :233.

Roseberry, J. 1962. Avian mortality in southern Illinois resulting from severe weather conditions. Ecology 43:739–740.

Sanborn, C. C. 1921. The season. Chicago region. Bird-Lore 23 (6) :308–309.

———. 1922*a*. The season. Chicago region. Bird-Lore 24 (4) : 222–223.

———. 1922*b*. Recent notes from an old collecting ground in north-eastern Illinois. Auk 39 (3) :367–373.

———, and W. A. Goelitz. 1915. A two-year nesting record in Lake County, Illinois. Wilson Bulletin 27 (4) :434–448.

Schafer, J. J. 1917. Winter notes. Audubon Bulletin, Spring 1917:55–56.

———. 1918. Winter notes from Port Byron. Audubon Bulletin, Spring and Summer 1918: 41–42.

———. 1920. Notes from Port Byron. Audubon Bulletin, Fall 1920:21–22.

———. 1921. Notes from the field revised to Dec. 15, 1921. Audubon Bulletin, Fall 1921:39–41.

———. 1922. [Winter notes.] Audubon Bulletin, Spring 1922: 37–38.

———. 1923. Notes from Port Byron. Audubon Bulletin, Fall 1923:37.

———. 1933. Port Byron. Audubon Bulletin 23:56.

Schantz, O. M. 1934–1935. A flicker tournament. Audubo Bulletin 24–25:43–45.

Scherer, C., M. Hundley, and H. Shaw. 1959. Winter bird population study. 18. Shrubby field and lake. Audubon Fiel Notes 13 (3) :336.

———, and H. Shaw. 1960. Winter bird-population study. 20 Shrubby field and lake. Audubon Field Notes 14 (3) :353.

Scott, T. G., Y. L. Willis, and J. A. Ellis. 1959. Some effect of a field application of dieldrin on wildlife. Journal o Wildlife Management 23 (4) :409–427.

Segal, S. 1960. Bird tragedy at the Dunes. The Indiana Audubon Quarterly 38 (2) :23–25.

Shaw, H. A. 1959. Illinois field notes—spring, 1959. Audubo Bulletin 110:6–7.

Shaw, V. S. 1958. Winter bird-population study. 13. Shrubby field and lake. Audubon Field Notes 12 (3) :312–313.

———. 1961. Winter bird-population study. 25. Shrubby fiel and lake. Audubon Field Notes 15 (3) :371.

———. 1962. Winter bird-population study. 17. Shrubby field and lake. Audubon Field Notes 16 (3) :374.

———. 1964. Winter bird-population study. 29. Shrubby field and lake. Audubon Field Notes 18 (3) :410.

———, C. Scherer, W. Bridges, and M. Hundley. 1956. Winter bird-population study. 25. Shrubby field and forest edge Audubon Field Notes 10 (3) :297.

———, ———, and M. Hundley. 1968. Winter bird population study. 26. Shrubby field and lake. Audubon Field Notes 22 (3) : 492.

———, and P. M. Stine. 1955. Winter bird population study 29. Shrubby field and forest edge. Audubon Field Notes 9 (3) :304.

Silloway, P. M. 1906. A novice's note-book—No. 5. Oölogist 23 (9) :139–140.

Smith, E. T., and W. J. Beecher. 1958. Chicagoland birds. Chicago Natural History Museum. 48 p.

———, and P. A. DuMont. 1945*a*. Fall migration. Middle-western region. Audubon Magazine, Section 2, 47 (1) :6–7.

———, and ———. 1945*b*. Winter season 1944–45. Middle-western region. Audubon Magazine 47 (3) :21–22 (Supplement) .

Smith, F. 1925. Interesting results from bird banding activities. Illinois State Academy of Science Transactions 18:107–112.

———. 1930. Records of spring migration of birds at Urbana, Illinois, 1903–1922. Illinois Natural History Survey Bulletin 19 (2) :105–117.

Smith, H. R., and P. W. Parmalee. 1955. A distributional check list of the birds of Illinois. Illinois State Museum Popular Science Series 4. 62 p.

Snyder, D., C. Bonney, and W. B. Robertson. 1948. Twelfth breeding-bird census. 15. Deciduous flood-plain forest. Audubon Field Notes 2 (6) :237.

Southern, W. E. 1962. Hybrid flicker (*Colaptes cafer* × *C. auratus*) in northeastern Illinois. Audubon Bulletin 121:5.

———. 1963. Three species observed anting on a wet lawn. Wilson Bulletin 75 (3) :275–276.

———. 1966. Utilization of shad as winter food by birds. Auk 83 (2) :309–311.

Starrett, W. C. 1936. Some bird notes from central Illinois. Wilson Bulletin 48 (1) :53.

———. 1938. Highway casualties in central Illinois during 1937. Wilson Bulletin 50 (3) :193–196.

Stickel, D. W. 1962. Predation on red-bellied woodpecker nestlings by a black rat snake. Auk 79 (1) :118–119.

———. 1963. Interspecific relations among red-bellied and hairy woodpeckers and a flying squirrel. Wilson Bulletin 75 (2) :203–204.

———. 1964. Roosting habits of red-bellied woodpeckers. Wilson Bulletin 76 (4) :382–383.

———. 1965. Territorial and breeding habits of red-bellied woodpeckers. American Midland Naturalist 74 (1) :110–118.

Stine, P. 1949. Thirteenth breeding-bird census. 28. Shrubby field and forest edge. Audubon Field Notes 3 (6) :271.

Stine, P. M., and C. Scherer. 1948. Winter bird-population study. 15. Mixed habitats: shrubby field and forest edge. Audubon Field Notes 2 (3) :161.

Stoddard, H. L. 1920. Arctic three-toed woodpecker in the Chicago area. Audubon Bulletin, Fall 1920:27.

———, and R. A. Norris. 1967. Bird casualties at a Leon County, Florida TV tower: an eleven-year study. Tall Timbers Research Station Bulletin 8. 104 p.

Strode, W. S. 1888. Fun among the birds. Ornithologist and Oölogist 13 (6) : 95.

———. 1892. Brief Notes. Ornithologist and Oölogist 17 (3) :47.

———. 1911. The pileated woodpecker. Oölogist 28 (4) :71–72.

Swink, Floyd A. 1959. A four-year survey of the ecology of land birds of the Chicago area—Part one. Audubon Bulletin 111:11–13.

———. [1965.] Birds of Morton Arboretum. Privately printed. 33 p.

Tanner, J. T. 1942. The ivory-billed woodpecker. National Audubon Society Research Report 1. 111 p.

Test, F. H. 1969. Relation of wing and tail color of the woodpeckers *Colaptes auratus* and *C. cafer* to their food. Condor 71 (2) :206–211.

Twomey, A. C. 1945. The bird population of an elm-maple forest with special reference to aspection, territorialism and coactions. Ecological Monographs 15 (2) :173–205.

Vandercook, C. B. 1919. Bags trumpeter swan. Oölogist 36 (8) : 133–134.

Voigt, J. W., and R. H. Mohlenbrock. 1964. Plant communities of southern Illinois. Southern Illinois University Press, Carbondale. 202 p.

Vredenburgh, A. 1905. Notes on winter feeding from Curran, Illinois. Bird-Lore 7 (5) :244–245.

Waldbauer, G. P., J. G. Sternburg, W. G. George, and A. G. Scarbrough. 1970. Hairy and downy woodpecker attacks on cocoons of urban *Hylophora cecropia* and other Saturniids (Lepidoptera). Entomological Society of America Annals 63 (5) :1366–1369.

Wall, M. L., and W. H. Whitcomb. 1964. The effect of bird predators on winter survival of the southwestern and European corn borers in Arkansas. Kansas Entomological Society Journal 37 (3) :187–192.

Walter, H. E., and A. H. Walter. 1904. Wild birds in city parks. A. W. Mumford, Chicago. 40 p.

Weber, A. J. 1966. An unusual flight of red headed woodpeckers. Iowa Bird Life 36 (4) :110.

Webster, F. M. 1881. Cecropia cocoons punctured by the hairy woodpecker. American Naturalist 15:241–242.

Weise, C. M. 1951. Breeding populations and reproductive success of birds of the forest and forest-edge in central Illinois. M.S. Thesis. University of Illinois. 123 p.

Widmann, O. 1907. A preliminary catalog of the birds of Missouri. Academy of Science of St. Louis Transactions 17 (1). 288 p.

Willard, F. C. 1896. A murderous woodpecker. Osprey 1 (1) :12.

Williams, J. B. 1975. Habitat utilization by four species of woodpeckers in a central Illinois woodland. American Midland Naturalist 93 (2) :354–367.

Williams, R. 1924. Right in the city. Audubon Bulletin, Spring and Summer 1924:30–31.

Willson, M. F. 1970. Foraging behavior of some winter birds of deciduous woods. Condor 72 (2) :169–174.

Winkenwerder, H. A. 1902. The winter habits of the red-headed woodpecker. Wisconsin Natural History Society Bulletin 2 (1) :69–74.

Woodruff, F. M. 1907. The birds of the Chicago Area. Chicago Academy of Sciences Natural History Survey Bulletin 6. 221 p.

Work, R. 1933. Field notes. Barrington bird club. Audubon Bulletin 23:41–42.

Wright, E. G. 1926. Spring birds of a city park. Oölogist 43 (2) :28.

Yeager, L. E. 1949. Effect of permanent flooding in a river-bottom timber area. Illinois Natural History Survey Bulletin 25 (2) :33–65.

———. 1955. Two woodpecker populations in relation to environmental change. Condor 57 (3) :148–153.

Zimmer, G. 1921. Notes from the field revised to Dec. 15, 1921. Audubon Bulletin, Fall 1921:43–44.

Zimmermann, M. H., and J. A. Milburn, editors. 1975. Transport in plants I. Springer-Verlag, Berlin. 535 p.

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THE TYPES OF COLLEMBOLA (INSECTA) AT THE ILLINOIS NATURAL HISTORY SURVEY

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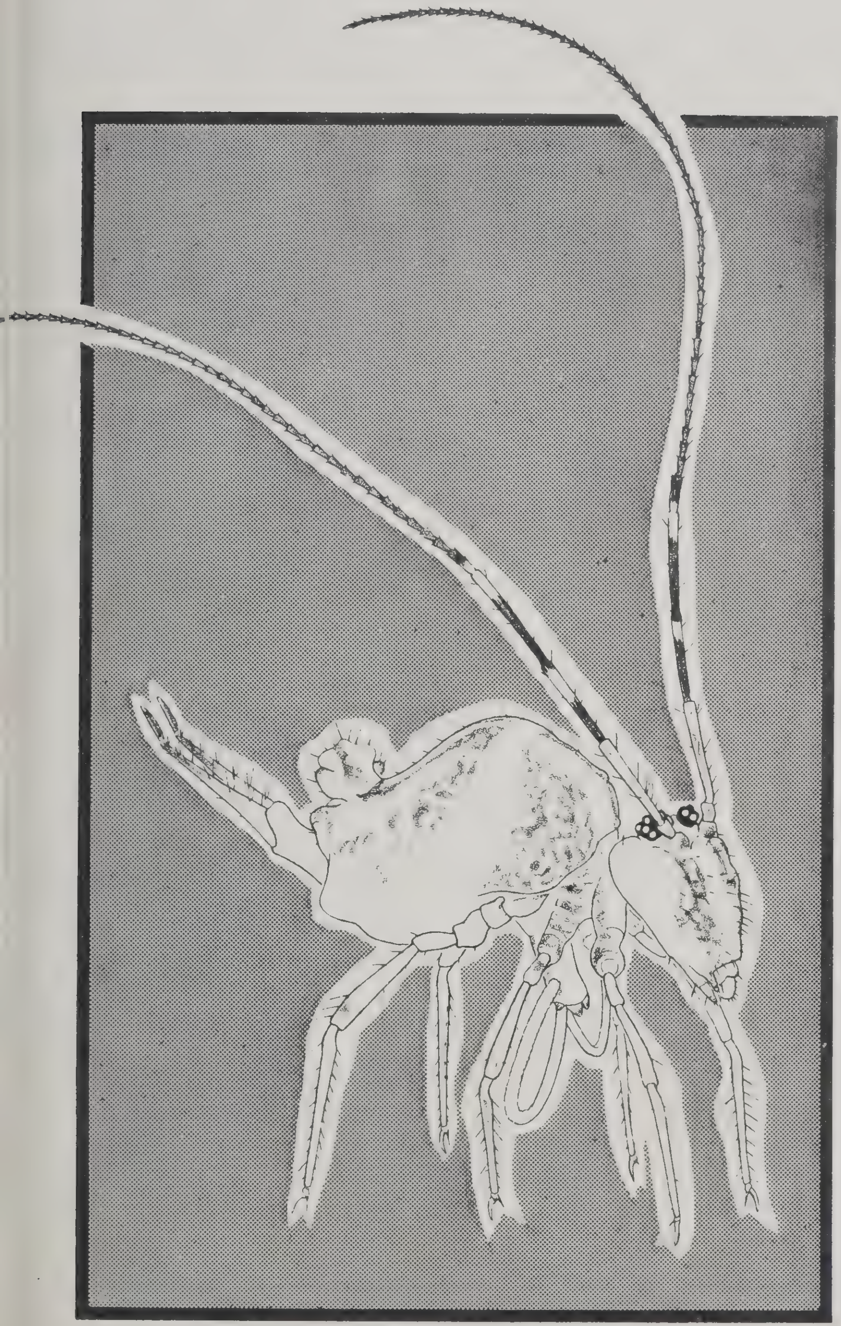

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Urbana, Illinois - February 1978

The Types of Collembola (Insecta) at the Illinois Natural History Survey

José A. Mari Mutt

Through the efforts of many people, among whom the late Dr. Harlow B. Mills deserves special credit, the collection of Collembola of the Illinois Natural History Survey has become one of the largest and most complete in the Western Hemisphere. Nevertheless, no list of the types has been published. This paper provides this list, making an important collection more accessible to workers in the field.

Types of 218 species and subspecies, including all primary and secondary types, are in the collection of the Illinois Natural History Survey. Generic and specific names are arranged in alphabetical sequence under each family. Each species name is followed by its author, the year of publication, and the number of the page on which the species description begins. This information is followed by the amount and kind of type material in the collection. The section on literature provides the reference to the original description of each species.

With the exception of the generic name *Achorutes,* which has been placed on the *Official Index of Rejected and Invalid Names in Zoology* (ICZN 1956) and for which the name *Hypogastrura* has been substituted (ICZN 1956), no further reference is made to synonymy. Author names placed in parentheses reflect the official change of *Achorutes,* under which the species was originally described, to *Hypogastrura.* All names of genera and species are cited exactly as they appear in the original descriptions of the species except that a few species names have had their endings changed so that they agree in gender with the names of their genera.

I wish to thank Dr. Kenneth A. Christiansen, Department of Biology, Grinnell College, Grinnell, Iowa, for kindly reviewing the manuscript and Mrs. Alice Ann Prickett for drawing the cover illustration.

LIST OF TYPES

Family PODURIDAE *sensu lato*

Acherontides atoyacense Bonet 1945: 28 (10 paratypes)

Anoura magna MacGillivray 1893*a*: 128 (leg of a syntype)

Anurida amorita Folsom 1902*b*: 90 (5 syntypes)

Anurida hammeri Christiansen 1951*b*: 135 (1 paratype)

Brachystomella agrosa Wray 1953*b*: 148 (2 syntypes)

Friesea grandis Mills 1934: 21 (1 syntype)

Friesea pentacantha Mills 1934: 20 (1 syntype)

Gnathocephalus aureofasciatus Harvey 1898: 216 (head of a syntype)

Gnathocephalus complexus MacGillivray 1893*b*: 318 (head of a syntype)

Hypogastrura brevispina (Harvey) 1893*b*: 182 (2 syntypes)

Hypogastrura (Schoettella) caeca (Folsom) 1927: 4 (75 syntypes)

Hypogastrura consanguinea (Folsom) 1924*b*: 506 (37 syntypes in one vial) An additional vial contains many syntypes mixed with specimens of *Hypogastrura matura.*

Hypogastrura harveyi (Folsom) 1902*a*: 320 (81 syntypes)

Hypogastrura humi (Folsom) 1916: 487 (95 syntypes)

Hypogastrura jondavi (Wray) 1946: 79 (1 complete syntype and parts of a second)

Hypogastrura macgillivrayi (Folsom) 1916: 488 (over 1,000 syntypes)

Hypogastrura (Schoettella) minutissima (Mills) 1934: 14 (11 syntypes)

Hypogastrura packardi (Folsom) 1902*a*: 319 (350 syntypes)

Hypogastrura packardi dentata (Folsom) 1902*a*: 320 (111 syntypes)

Hypogastrura pseudarmata (Folsom) 1916: 490 (over 1,000 syntypes)

Hypogastrura thomomys (Chamberlain) 1943: 39 (328 syntypes)

Hypogastrura tigrina (Harvey) 1900: 552 (3 syntypes)

Micranurida furcifera Mills 1934: 27 (2 syntypes)

Morulina callowayia Wray 1953*a*: 1 (3 paratypes)

Neanura persimilis Mills 1934: 30 (31 syntypes)

Neanura serrata Folsom 1916: 511 (fragments of a syntype)

Odontella cornifer Mills 1934: 25 (5 syntypes)

Odontella ewingi Folsom 1916: 502 (6 syntypes)

Paranura caeca Folsom 1916: 507 (5 syntypes)

Paranura sexpunctata colorata Mills 1934: 28 (5 syntypes)

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. José A. Mari Mutt is a graduate student in the Department of Entomology, University of Illinois, and a Research Assistant at the Illinois Natural History Survey.

Cover Illustration.—*Temeritas womersleyi* (Denis) after a specimen deposited at the Illinois Natural History Survey. Drawing by Mrs. Alice Ann Prickett.

Protanura capitata Folsom 1932: 56 (4 syntypes)
Schaefferia variabilis Christiansen 1951*b*: 125 (8 paratypes)
Schoettella alba Folsom 1932: 54 (1 syntype)
Stachia minuta Folsom 1932: 55 (65 syntypes)
Willemia denisi Mills 1932: 263 (2 syntypes)
Willemia intermedia Mills 1934: 17 (4 syntypes)
Willemia persimilis Bonet 1945: 37 (2 syntypes)
Willemia similis Mills 1934: 17 (8 syntypes)
Xenylla alba Folsom 1932: 54 (6 syntypes)
Xenylla baconae Folsom 1916: 496 (217 syntypes)
Xenylla sensilis Folsom 1932: 54 (12 syntypes)
Xenylla welchi Folsom 1916: 497 (over 1,000 syntypes)
Xenylla yucatana Mills 1938: 183 (2 syntypes)

Family ONYCHIURIDAE

Aphorura cocklei Folsom 1908: 200 (63 syntypes)
Onychiurus irregularis Chamberlain 1943: 43 (2 syntypes)
Onychiurus millsi Chamberlain 1943: 42 (2 syntypes)
Onychiurus obesus Mills 1934: 35 (10 syntypes)
Onychiurus parvicornis Mills 1934: 33 (68 syntypes)
Onychiurus pseudofimetarius Folsom 1917: 650 (1 syntype)
Onychiurus subtenuis Folsom 1917: 642 (14 syntypes)
Onychiurus wilchi Wray 1950: 98 (8 syntypes)
Tullbergia clavata Mills 1934: 38 (19 syntypes)
Tullbergia granulata Mills 1934: 37 (1 paratype)
Tullbergia iowensis Mills 1932: 364 (22 syntypes)
Tullbergia silvicola Folsom 1932: 57 (3 syntypes)

Family ISOTOMIDAE

Hypogastrura longispina (MacGillivray) 1893*b*: 315 (over 500 syntypes)
Boernerella octogenaria Mills & Schmidt 1957: 368 (46 syntypes)
Denisia falcata Folsom 1932: 61 (1 syntype and fragments of a second)
Folsomia decaxiophthalma Ford 1962: 131 (1 paratype)
Folsomia duodecimoculata Ford 1962: 130 (1 paratype)
Folsomia fimetaria dentata Folsom 1927: 7 (1 syntype)
Folsomia macroseta Ford 1962: 129 (1 paratype)
Folsomia prima Mills 1931: 3 (2 syntypes)
Folsomia silvestrii Folsom 1937: 20 (2 syntypes)
Folsomia sylvia Wray 1953*b*: 148 (1 syntype)
Folsomides decemoculatus Mills 1935: 134 (over 500 syntypes)
Folsomides parvus Folsom *in* Mills 1934: 43 (2 syntypes)
Folsomides stachi Folsom *in* Mills 1934: 45 (1 syntype)
Guthriella antigua Folsom 1937: 34 (33 syntypes)
Isotoma andrei Mills 1934: 58 (10 syntypes)
Isotoma caeruleatra Guthrie 1903: 70 (11 syntypes)
Isotoma capitola MacGillivray 1896: 56 (2 legs of a syntype)
Isotoma (Isotoma) difficilis Folsom 1937: 89 (5 syntypes)
Isotoma eunotabilis Folsom *in* Mills 1934: 58 (16 syntypes)
Isotoma (Isotoma) gelida Folsom 1937: 106 (18 syntypes)
Isotoma glauca montana MacGillivray 1896: 57 (2 syntypes)
Isotoma immersa Folsom 1924*a*: 1 (over 500 syntypes)
Isotoma macnamarai Folsom 1918: 291 (3 syntypes)
Isotoma (Isotoma) marissa Folsom 1937: 89 (11 syntypes)
Isotoma nigrifrons Folsom *in* Mills 1934: 60 (207 syntypes)
Isotoma nivalis Packard 1873: 31 (2 syntypes and fragments of a third)
Isotoma obsoleta MacGillivray 1896: 54 (fragments of a syntype)
Isotoma sepulcralis Folsom 1902*c*: 364 (281 syntypes)
Isotoma spatulata Chamberlain 1943: 43 (2 syntypes)
Isotoma (Isotoma) subaequalis Folsom 1937: 107 (1 syntype and fragments of a second)
Isotoma terminata MacGillivray 1896: 56 (2 syntypes)
Isotoma tridentata MacGillivray 1896: 51 (fragments of a syntype)
Isotoma trispinata MacGillivray 1896: 51 (1 syntype)
Isotoma (Isotoma) viridis pomona Folsom 1937: 115 (2 syntypes)
Isotomodes denisi Folsom 1932: 59 (3 syntypes)
Isotomodes tenuis Folsom *in* Mills 1934: 46 (2 syntypes)
Isotomurus bemakus Wray 1952: 102 (5 syntypes)
Isotomurus palustris texensis Folsom 1937: 76 (56 syntypes)
Isotomurus retardatus Folsom 1937: 71 (2 syntypes)
Micrisotoma achromata Bellinger 1952: 20 (1 paratype)
Proisotoma americana Mills 1934: 51 (14 syntypes)
Proisotoma bayouensis Mills 1931: 1 (131 syntypes)
Proisotoma (Proisotoma) bulbosa Folsom 1937: 58 (1 syntype)
Proisotoma (Proisotoma) cognata Folsom 1937: 65 (19 syntypes)
Proisotoma (Proisotoma) constricta Folsom 1937: 64 (17 syntypes and fragments of about 6 others)
Proisotoma (Ballistura) excavata Folsom 1937: 41 (109 syntypes)
Proisotoma (Proisotoma) frisoni Folsom 1937: 55 (1 syntype)
Proisotoma (Ballistura) laticauda Folsom 1937: 42 (fragments of a syntype)
Proisotoma nigromaculosa Folsom 1932: 62 (9 syntypes)

Proisotoma (Proisotoma) rainieri Folsom 1937: 45 (1 syntype)
Proisotoma (Proisotoma) simplex Folsom 1937: 61 (over 1,000 syntypes)
Proisotoma (Proisotoma) tenelloides Folsom 1937: 62 (4 syntypes)
Proisotoma (Proisotoma) titusi Folsom 1937: 49 (14 syntypes)
Proisotoma (Proisotoma) vesiculata Folsom 1937: 57 (10 syntypes)
Protanurophorus pearmani Womersley 1925: 251 (1 syntype)
Pseudanurophorus arcticus Christiansen 1951*b*: 131 (7 paratypes)
Spinisotoma (Spinisotoma) dispersa Wray 1952: 100 (4 syntypes)
Uzelia hansoni Mills & Richards 1953: 55 (70 syntypes)
Weberacantha octa Christiansen 1951*a*: 25 (1 paratype)

Family ENTOMOBRYIDAE *sensu lato*

Borecus pinnatus Folsom 1923: 399 (16 syntypes)
Cyphoderus innominatus Mills 1938: 186 (1 syntype)
Cyphoderus similis Folsom 1927: 12 (8 syntypes, 2 without the head)
Degeeria decemfasciata Packard 1873: 40 (2 syntypes)
Degeeria griseoolivata Packard 1873: 39 (1 syntype)
Degeeria perpulchra Packard 1873: 38 (4 syntypes)
Dicranocentroides (Dicranocentropha) sabana Wray 1953*b*: 144 (4 syntypes)
Dicranocentruga jataca Wray 1953*b*: 143 (4 paratypes)
Dicranocentrus (Dicranocentrella) marias Wray 1953*b*: 141 (lectotype and 20 paralectotypes)
Dicranocentrus meruensis Wahlgren 1908: 3 (5 paralectotypes)
Dicranorchesella boneti Mari Mutt 1977*b*: 381 (holotype and 31 paratypes)
Drepanocyrtus terrestris Folsom 1932: 69 (58 syntypes)
Drepanura kanaba Wray 1953*a*: 4 (3 syntypes)
Drepanura rolfsi Mills 1935: 134 (1 syntype)
Entomobrya assuta Folsom 1924*a*: 6 (9 syntypes)
Entomobrya caeca Schött 1896: 178 (8 syntypes)
Entomobrya comparata Folsom 1919: 13 (3 syntypes)
Entomobrya cubensis Folsom 1927: 7 (21 syntypes)
Entomobrya frontalis Mills 1935: 136 (34 syntypes)
Entomobrya guthriei Mills 1931: 4 (7 syntypes)
Entomobrya intonsa Mills 1932: 265 (5 syntypes)
Entomobrya lactea Folsom 1932: 65 (5 syntypes)
Entomobrya ligata Folsom 1924*a*: 3 (7 syntypes)
Entomobrya mineola Folsom 1924*a*: 5 (4 syntypes)
Entomobrya nigriceps Mills 1932: 268 (5 syntypes)
Entomobrya pseudoperpulchra Mills 1931: 5 (13 syntypes)
Entomobrya quadrilineata Bueker 1939: 15 (2 syntypes)
Entomobrya (Drepanura) sabulicola Mills 1931: 7 (1 syntype)
Entomobrya washingtonia Mills 1935: 135 (8 syntypes)
Heteromurus stannardi Mari Mutt 1977*a*: 326 (2 paratypes)
Lepidocyrtus caprilesi Wray 1953*b*: 145 (holotype and 2 paratypes)
Lepidocyrtus cephalopurpureus Harvey 1894: 324 (1 syntype)
Lepidocyrtus cyaneus cinereus Folsom 1924*a*: 9 (13 syntypes)
Lepidocyrtus folsomi Mills 1931: 10 (10 syntypes)
Lepidocyrtus intermixtus Folsom 1924*c*: 75 (5 syntypes)
Lepidocyrtus nigrosetosus Folsom 1927: 9 (1 syntype)
Lepidocyrtus pearsei Mills 1938: 188 (22 syntypes)
Lepidocyrtus pistiae Paulian & Delamare-Deboutteville 1945: 138 (1 syntype)
Lepidocyrtus unifasciatus neofasciatus Wray 1948: 44 (1 syntype)
Lepidocyrtus usitatus Folsom 1927: 8 (2 syntypes, 1 without the head)
Lepidocyrtus violentus Folsom 1924*a*: 10 (19 syntypes)
Oncopodura cruciata Bonet 1943: 141 (10 syntypes)
Oncopodura oculata Mills 1937: 67 (12 syntypes)
Oncopodura prietoi Bonet 1943: 147 (fragments of a paratype)
Orchesella ainsliei Folsom 1924*a*: 6 (14 syntypes)
Orchesella alpa Christiansen & Tucker 1977: 8 (undeterminate number of paratypes)
Orchesella annulicornis Mills 1934: 78 (34 syntypes)
Orchesella bulba Christiansen & Tucker 1977: 1 (holotype and 8 paratypes)
Orchesella celsa Christiansen & Tucker 1977: 3 (holotype and 41 paratypes)
Orchesella fishmani Christiansen & Tucker 1977: 5 (holotype and 41 paratypes)
Orchesella flavopicta Packard 1873: 41 (2 syntypes, 1 without the head)
Orchesella zebra Guthrie 1903: 61 (26 syntypes)
Pseudocyphoderus melittophilous Mari Mutt 1977*d*: 229 (2 paratypes)
Pseudosinella rolfsi Mills 1932: 272 (6 syntypes)
Pseudosinella subfusa Wray 1953*b*: 149 (1 syntype)
Salina decorata Mills 1932: 273 (7 syntypes)
Salina maculata Folsom 1932: 71 (8 syntypes)
Salina wolcotti Folsom 1927: 11 (10 syntypes)
Seira mexicana Folsom 1898: 184 (35 syntypes)
Sulcuncus falciferus Mills 1938: 190 (1 syntype)
Tomocerus flavescens separatus Folsom 1913: 460 (5 syntypes)
Tomocerus lamelliferus Mills 1934: 84 (47 syntypes)
Tomocerus (Tritomurus) missus Mills 1948: 356 (24 syntypes)
Tomolonus reductus Mills 1948: 353 (16 syntypes)
Troglolaphysa maya Mills 1938: 184 (1 syntype)

Family SMINTHURIDAE *sensu lato*

Arrhopalites diversus Mills 1934: 93 (14 syntypes)
Bourletiella millsi Pedigo 1968: 554 (4 paratypes)
Dicyrtoma mithra Wray 1949: 63 (2 paratypes)
Dicyrtoma quadrangularis Mills 1934: 106 (1 syntype)
Dicyrtomina rossi Wray 1952: 97 (1 paratype)
Megalothorax bolivari Bonet 1944: 23 (1 paratype)
Megalothorax incertoides Mills 1934: 85 (1 syntype)
Neelus minutus Folsom 1901: 221 (5 syntypes)
Neelus murinus Folsom 1896*a*: 391 (4 syntypes)
Neosminthurus occidentalis Mills 1935: 138 (5 syntypes)
Neosminthurus sminthurinus Mills 1934: 99 (3 syntypes, 1 without the head)
Papirius marmoratus Packard 1873: 42 (7 syntypes)
Papirius olympius MacGillivray 1894: 110 (28 syntypes)
Papirius palmatus Folsom 1902*b*: 102 (5 syntypes)
Papirius purpurescens MacGillivray 1894: 109 (2 syntypes)
Papirius texensis Packard 1873: 42 (1 syntype)
Papirius unicolor Harvey 1893*a*: 65 (4 syntypes)
Papirius vittatus Folsom 1896*d*: 119 (4 syntypes)
Pseudobourletiella chandleri Pedigo 1968: 550 (holotype and 3 paratypes)
Ptenothrix aurata Mills 1934: 107 (3 syntypes)
Ptenothrix dominicana Mari Mutt 1977*c*: 285 (1 paratype)
Sminthurides globocerus Folsom & Mills 1938: 240 (18 syntypes)
Sminthurides lepus Mills 1934: 91 (7 syntypes)
Sminthurides macnamarai Folsom & Mills 1938: 258 (18 syntypes)
Sminthurides occultus Mills 1934: 91 (33 syntypes)
Sminthurides penicillifer bifidus Mills 1934: 90 (6 syntypes)
Sminthurides ramosus Folsom 1932: 72 (9 syntypes)
Sminthurides (Sphaeridia) serratus Folsom & Mills 1938: 268 (32 syntypes)
Smynthurus albamaculatus Harvey 1897: 124 (2 syntypes)
Smynthurus amicus Folsom 1896*b*: 447 (4 syntypes)
Smynthurus fitchi Folsom 1896*b*: 449 (2 syntypes)
Smynthurus floridanus MacGillivray 1893*a*: 127 (1 syntype)
Smynthurus henshawii Folsom 1896*b*: 449 (9 syntypes)
Sminthurus medialis Mills 1934: 103 (29 syntypes)
Smynthurus minutus MacGillivray 1894: 109 (2 syntypes)
Sminthurus obscurus Mills 1934: 104 (3 syntypes)
Smynthurus packardi Folsom 1896*c*: 385 (3 syntypes)
Smynthurus spinatus MacGillivray 1893*a*: 127 (20 syntypes)
Sphyrotheca aleta Wray 1953*b*: 149 (holotype)

LITERATURE CITED

BELLINGER, P. F. 1952. A new genus and species of Isotomidae (Collembola). Psyche 59:20–25.

BONET, F. 1943. Sobre la clasificación de los Oncopoduridae (Collembola), con descripción de especies nuevas. Escuela Nacional de Ciencias Biológicas Anales 3:127–153.

———. 1944. Sobre el género *Metasinella* Denis, y algunos otros Colémbolos cavernícolas de Cuba. Ciencia 5:17–24.

———. 1945. Nuevos géneros y especies de Hipogastruridos de México (Collembola). Sociedad Mexicana de Historia Natural Revista 6:13–45; 6 plates.

BUEKER, E. D. 1939. Springtails (Collembola) of the St. Louis area. Academy of Science of St. Louis Transactions 30:1–30.

CHAMBERLAIN, R. W. 1943. Four new species of Collembola. Great Basin Naturalist 4:39–48.

CHRISTIANSEN, K. A. 1951*a*. Notes on Alaskan Collembola. I. A new genus and species of the family Isotomidae. Psyche 58: 24–31.

———. 1951*b*. Notes on Alaskan Collembola. II. Three new species of Arctic Collembola. Psyche 58:125–140.

———, and B. E. TUCKER. 1977. Five new species of *Orchesella* (Collembola: Entomobryidae). Iowa Academy of Sciences Proceedings 84:1–13.

FOLSOM, J. W. 1896*a*. *Neelus murinus*, representing a new Thysanuran family. Psyche 7:391–392; 1 plate.

———. 1896*b*. New Smynthuri, including myrmecophilous and aquatic species. Psyche 7:446–450; 1 plate.

———. 1896*c*. Notes on the types of *Papirius texensis* Pack. and description of a new *Smynthurus*. Psyche 7:384–385.

———. 1896*d*. Two new species of *Papirius*. Canadian Entomologist 28:119–121.

———. 1898. Descriptions of species of *Machilis* and *Seira* from Mexico. Psyche 8:183–184; 1 plate.

———. 1901. Review of the Collembolan genus *Neelus* and description of *N. minutus* n. sp. Psyche 9:219–222; 1 plate.

———. 1902*a*. The identity of the snow-flea (*Achorutes nivicola* Fitch). Psyche 9:315–321; 1 plate.

———. 1902*b*. Papers from the Harriman Alaska expedition. XXVII. Apterygota. Washington Academy of Sciences Proceedings 4:87–116.

———. 1902*c*. Collembola of the grave. Psyche 9:363–367; 1 plate.

———. 1908. The golden snow-flea, *Aphorura cocklei*. Canadian Entomologist 40:199–201; 1 plate.

———. 1913. North American spring-tails of the subfamily Tomocerinae. U.S. National Museum Proceedings 46:451–472; 2 plates.

———. 1916. North American Collembolous insects of the subfamilies Achorutinae, Neanurinae, and Podurinae. U.S. National Museum Proceedings 50:477–525; 19 plates.

———. 1917. North American collembolous insects of the subfamily Onychiurinae. U.S. National Museum Proceedings 53:637–659; 12 plates.

———. 1918. A new *Isotoma* of the snow fauna. Canadian Entomologist 50:291–292; 1 plate.

———. 1919. Collembola of the Canadian Arctic expedition, 1913–18. Pages 1a–29a *in* Report of the Canadian Arctic expedition 1913–18. Vol. 3: Insects. Part A: Collembola.

———. 1923. Termitophilous Apterygota from British Guiana. Zoologica 3:383–402.

———. 1924*a*. New species of Collembola from New York state. American Museum Novitates 1924(108):1–12.

———. 1924*b*. East Indian Collembola. Harvard College Museum of Comparative Zoology Bulletin 65(14):505–517; 5 plates.

———. 1924*c*. Apterygota of the Williams Galapagos expedition. Zoologica 5:67–76.

———. 1927. Insects of the subclass Apterygota from Central

America and the West Indies. U.S. National Museum Proceedings 72:1–16; 8 plates.

———. 1932. Hawaiian Collembola. Hawaiian Entomological Society Proceedings 8:51–92.

———. 1937. Nearctic Collembola, or springtails, of the family Isotomidae. U.S. National Museum Bulletin 168. 144 p.

———, and H. B. Mills. 1938. Contribution to the knowledge of the genus *Sminthurides* Börner. Harvard College Museum of Comparative Zoology Bulletin 82:231–274; 9 plates.

Ford, F. M. 1962. Notes on Tennessee Collembola, three new species of Isotomidae: *Folsomia*. Tennessee Academy of Sciences Journal 37(4):129–132.

Guthrie, J. E. 1903. The Collembola of Minnesota. Geological and Natural History Survey of Minnesota, Zoological Series IV, 110 p.; 16 plates.

Harvey, F. L. 1893*a*. A new *Papirius*. Entomological News 4:65–68.

———. 1893*b*. A new *Acharutes*. Entomological News 4:182–184.

———. 1894. A new species of *Lepidocyrtus*. Entomological News 5:324–326.

———. 1897. A new garden Smynthurid, *Smynthurus albamaculata* n. sp. Pages 124–126 *in* Twelfth Annual Report of the Maine Agricultural Experiment Station for 1896.

———. 1898. A new Poduran of the genus *Gnathocephalus*. Entomological News 9:216–217.

———. 1900. New Maine Collembola. Entomological News 11:549–553.

International Commission on Zoological Nomenclature. 1956. Opinion 435. Opinions and Declarations Rendered by the International Commission on Zoological Nomenclature 12: 427–457.

MacGillivray, A. D. 1893*a*. North American Thysanura. Canadian Entomologist 25:127–128.

———. 1893*b*. North American Thysanura—IV. Canadian Entomologist 25:313–318.

———. 1894. North American Thysanura—V. Canadian Entomologist 26:105–110.

———. 1896. The American species of *Isotoma*. Canadian Entomologist 28:47–58.

Mari Mutt, J. A. 1977*a*. A new species of *Heteromurus* from the Solomon Islands (Collembola: Entomobryidae). Pan-Pacific Entomologist 52:326–330.

———. 1977*b*. *Dicranorchesella,* a new genus of springtails from Mexico. Entomological Society of Washington Proceedings 79(3):377–382.

———. 1977*c*. Fifteen new records and a new species of Collembola from the Dominican Republic. Florida Entomologist 60(4):281–285.

———. 1977*d*. A new species of melittophilous *Pseudocyphoderus* from Costa Rica and remarks on taxonomy (Collembola: Cyphoderidae). Entomological News 88(9&10):229–234.

Mills, H. B. 1931. New Nearctic Collembola. American Museum Novitates 1931(464):1–11.

———. 1932. New and rare North American Collembola. Iowa State College Journal of Science 6:263–276.

———. 1934. A monograph of the Collembola of Iowa. Collegiate Press, Inc., Ames, Iowa. 143 p.

———. 1935. New Collembola from western North America. Brooklyn Entomological Society Bulletin 30:133–141.

———. 1937. A North American *Oncopodura* (Collembola). Canadian Entomologist 69:67–69.

———. 1938. Collembola from Yucatan caves. Pages 183–190 *in* A. S. Pearse, ed., Fauna of Yucatan caves. Carnegie Institute of Washington, D.C., Publication 491.

———. 1948. New North American Tomocerinae. Entomological Society of America Annals 41:353–359.

———, and W. R. Richards. 1953. Collembola from arctic and boreal Canada. Kansas Entomological Society Journal 26: 53–59.

———, and F. H. Schmidt. 1957. The *Coloburella-Boernerella* complex with description of a new species. Acta Zoologica Cracoviensia 11:365–372; 1 plate.

Packard, A. S., Jr. 1873. Synopsis of the Thysanura of Essex County, Mass., with descriptions of a few extralimital forms. Pages 23–51 *in* Fifth report of the trustees of the Peabody Academy of Science for 1872, appendix to the director's report.

Paulian, R., and C. Delamare-Deboutteville. 1945. Les insectes de *Pistia stratiotes* en Cote d'Ivoire. Société Entomologique de France Bulletin 49:135–139.

Pedigo, L. P. 1968. Pond shore Collembola: A redescription of *Salina banksii* MacGillivray (Entomobryidae) and new Sminthuridae. Kansas Entomological Society Journal 41: 548–556.

Schött, H. 1896. North American Apterygogenea. California Academy of Sciences Proceedings, 2nd Series, 6:169–196; 3 plates.

Wahlgren, E. 1908. Apterygogenea. 1. Collembola. Pages 1–10 *in* Wissenschaftliche Ergebnisse der Schwedischen Zoologischen Expedition nach dem Kilimandjaro, dem Meru und den Umgebenden Massaisteppen Deutsch-Ostafrikas 1905–1906 unter leitung von Prof. Dr. Yngve Sjöstedt. Almqvist & Wiksells Boktryckeri-A. B., Uppsala.

Womersley, H. 1925. Two new British Collembola. Entomologist's Monthly Magazine 61:250–252.

Wray, D. L. 1946. New Collembola from North Carolina. Brooklyn Entomological Society Bulletin 41:79–85.

———. 1948. Some new species and varieties of Collembola from North Carolina. Brooklyn Entomological Society Bulletin 43:44–53.

———. 1949. Some new *Dicyrtoma* and key to known species of the United States (Collembola, Sminthuridae). Brooklyn Entomological Society Bulletin 44:61–68.

———. 1950. Some new Nearctic Collembola. Psyche 57:95–100; 1 plate.

———. 1952. Some new North American Collembola. Brooklyn Entomological Society Bulletin 47:95–106.

———. 1953*a*. Some new species of springtail insects (Collembola). Nature Notes Occasional Papers 1:1–7.

———. 1953*b*. New Collembola from Puerto Rico. University of Puerto Rico Journal of Agriculture 37:140–150.

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Biology

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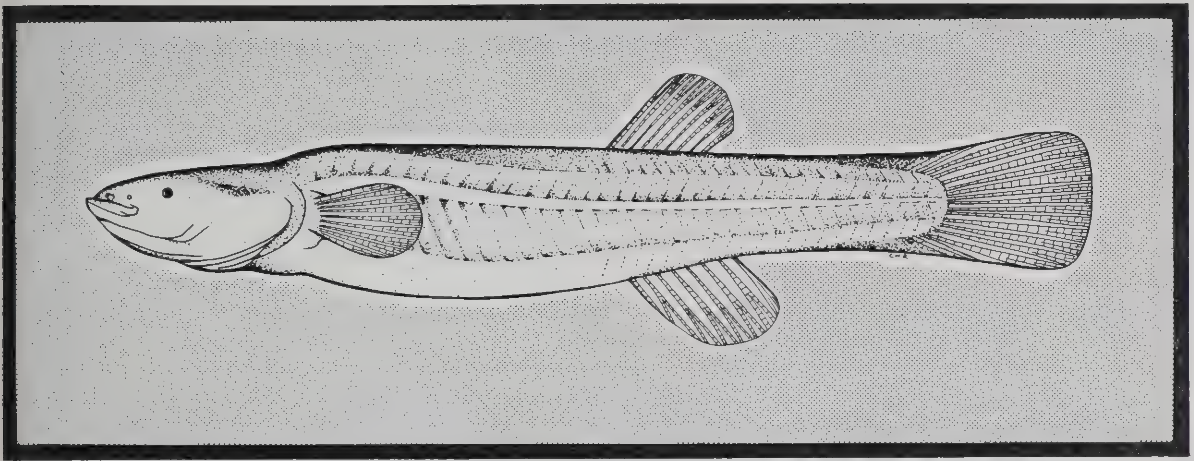
SUMMARY OF THE LIFE HISTORY AND DISTRIBUTION OF THE SPRING CAVEFISH, *Chologaster agassizi*, PUTNAM, WITH POPULATION ESTIMATES FOR THE SPECIES IN SOUTHERN ILLINOIS

PHILIP W. SMITH—NORBERT M. WELCH



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A Summary of the Life History and Distribution of the Spring Cavefish, *Chologaster agassizi* Putnam, with Population Estimates for the Species in Southern Illinois

Philip W. Smith and Norbert M. Welch

The genus *Chologaster,* which means mutilated belly in reference to the absence of pelvic fins, was proposed by Agassiz (1853:134) for a new fish found in ditches and rice fields of South Carolina and described by him as *C. cornutus.* Putnam (1872:30) described a second species of the genus found in a well at Lebanon, Tennessee, naming it *C. agassizi* for the author of the generic name. Forbes (1881:232) reported one specimen of *Chologaster* from a spring in western Union County, Illinois, and noted that it differed from known specimens of the two described species but did not assign a specific name to the Illinois population. After acquiring additional specimens, Forbes (1882:1) described it on the basis of color differences as a new species, *C. papilliferus.* Jordan & Gilbert ([1883]:325, 890) recognized all three species and noted that the two spring cavefishes (*agassizi* and *papilliferus*) occurred in Tennessee, Kentucky, and southern Illinois. Jordan & Evermann (1927:503) believed the different way of life between the epigean *C. cornutus* and the hypogean (subterranean) *C. papilliferus* warranted erection of a new genus for the latter and proposed *Forbesella,* but Jordan (1929:68) noted that *Forbesella* was preoccupied and suggested *Forbesichthys* as a substitute name.

Woods & Inger (1957) revised all species in the family Amblyopsidae and synonymized *C. papilliferus* under the earlier *C. agassizi,* although they pointed out that minor differences were observed from population to population. Their arrangement has been generally followed by subsequent authors, including Hill (1969*b*) who studied the effects of isolation upon meristic characters. Only Clay (1975:240) has maintained that *C. agassizi* and *C. papilliferus* are specifically distinct. Rosen (1962) discussed in detail the anatomy of amblyopsid fishes (including *Chologaster*) and their relationships to other fish families but did not concern himself with the validity of the described species.

Except for some studies of eye structure by Eigenmann (summarized in Eigenmann 1909), the nonsystematic literature on the spring cavefish consists mostly of new locality records and brief incidental accounts of behavior, habitat, food, and size classes (Forbes & Richardson 1908, 1920; Layne & Thompson 1952; Gunning & Lewis 1955). Weise (1957) summarized the prior work on the species and described in detail the habitat, phototaxis, thigmotaxis, rheotaxis, temperature tolerance, invertebrate and vertebrate species associates, and sexual dimorphism in a life-history study of the species at Pine Hills in Union County, Illinois. Poulson (1963) discussed various adaptations and comparative metabolic rates of all known amblyopsids. The next major contribution to our knowledge was a series of papers by Hill, who worked with the Warren County, Kentucky, population of spring cavefish and described oxygen preferences (1968), food and feeding habits (1969*a*), effects of isolation upon meristic characters (1969*b*), and the development of squamation in the young (1971). Whittaker & Hill (1968) described a new species of cestode parasite, naming it *Proteocephalus chologasteri.*

In the early 1970's, H. E. McReynolds of the U. S. Forest Service, became concerned about the status of the spring cavefish on the Shawnee National Forest in southern Illinois. He appointed a technical advisory committee to direct research designed to ascertain population size of the species in the LaRue-Pine Hills Ecological Area in Union County, Illinois, and hired one of us (Welch) to conduct censusing studies throughout 1973. In 1974 personnel from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey, under contract with the Forest Service, investigated the status of several unusual fishes, including the spring cavefish, on the Shawnee National Forest and prepared a report. Since that time Jeffrey J. Webb of Anna, Illinois, has independently censused spring cavefish in Cave Spring Cave, about 5½ miles northeast of Pine Hills, and kindly gave his population estimates to us.

This paper presents the population estimates and other data taken directly from the three recent reports and brief summaries of other aspects of the life history of the spring cavefish reported in the literature.

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The U. S. Department of Agriculture Forest Service initiated and supported most of the investigations upon which this paper is based and paid for its printing. Special thanks are due to H. E. McReynolds, Zone Fisheries Biologist, and to the personnel of the Harrisburg Forest Supervisor's Office and the Jonesboro Ranger, District of the Shawnee National Forest, for their interest and cooperation. Acknowledgment is also due to the *Chologaster* Technical Advisory Committee under the chairmanship of H. E. McReynolds. For aid with field work we are indebted to Larry M. Page, Brooks M. Burr, John A. Boyd, and Michael A. Morris of the Illinois Natural History Survey, and to the Survey for partial support of field work and for various administrative services. Marvin E. Braasch of Belleville, Illinois, supplied new records for Kentucky and Tennessee. Bernice P. Sweeney typed the manuscript, Craig W. Ronto prepared the drawings, and Larry M. Page and Larry Far-

Cover Illustration. — Spring cavefish. Drawing by Craig Ronto.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. Its printing was paid for by the U.S. Department of Agriculture Forest Service. Dr. Smith is a Taxonomist and Head of the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Welch is a physician on the staff of Parkland Hospital, Dallas, Texas.

low took the photographs. Assistant Technical Editor Shirley McClellan edited the manuscript, and John E. Cooper of the North Carolina Museum of Natural History served as guest reviewer. Larry M. Page and Brooks M. Burr kindly copied records of spring cavefish in several museum collections that they visited, and officials in charge of these collections made their holdings freely available. David H. Snyder of Austin Peay University (Tennessee) advised us of several collections. The collections include the Illinois Natural History Survey (INHS), Eastern Kentucky University (EKU), Kentucky Fish and Wildlife Department (KFW), Murray State University (MSU), University of Michigan Museum of Zoology (UMMZ), U.S. National Museum of Natural History (USNM), University of Louisville (UL), University of Oklahoma (UO), University of Tennessee (UT), University of Tulsa (UTULSAC), University of Alabama (UA), and Northeastern Louisiana University (NLU). Jeffrey J. Webb of Anna, Illinois, supplied a population estimate for Cave Spring Cave, and Claude D. Baker of the University of Illinois Dixon Springs Agricultural Station performed some water chemistry analyses for us. Finally, the Illinois Department of Conservation Division of Fisheries granted permission to collect specimens for these studies.

HABITAT AND BEHAVIOR

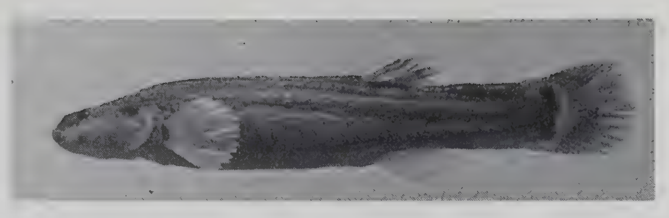

Fig. 1. — Adult spring cavefish from spring along Big Creek in Hardin County, Illinois.

The spring cavefish (Fig. 1) bridges the gap between an epigean and hypogean existence. It is known to occur in caves throughout most of its range, but it is much better known from springs, spring runs, and spring seeps (Fig. 2–4). It is subterranean, emerging at dusk and usually retreating underground an hour or two before dawn. It has eyes that appear functional but serve only to distinguish light and darkness (Hill 1969*a*). In southern Illinois its appearance above ground is strongly correlated with the amount of flow emerging from the springs and with the season. During dry seasons, some springs have no flow; others continue to flow but have only a few spring cavefish or none at all. Fish were found throughout the year in the LaRue-Pine Hills Ecological Area, but in fewer numbers in January, February, and March, and no gravid females were seen from January through May.

Fish from different springs were marked with various colors of tatoo ink so that when recaptured they could be identified with the spring in which they were initially found. The color coding was done deliberately to see if there was any mixing or exchange underground of individuals from adjacent springs. None was observed.

In tiles where spring water collected to form pools,

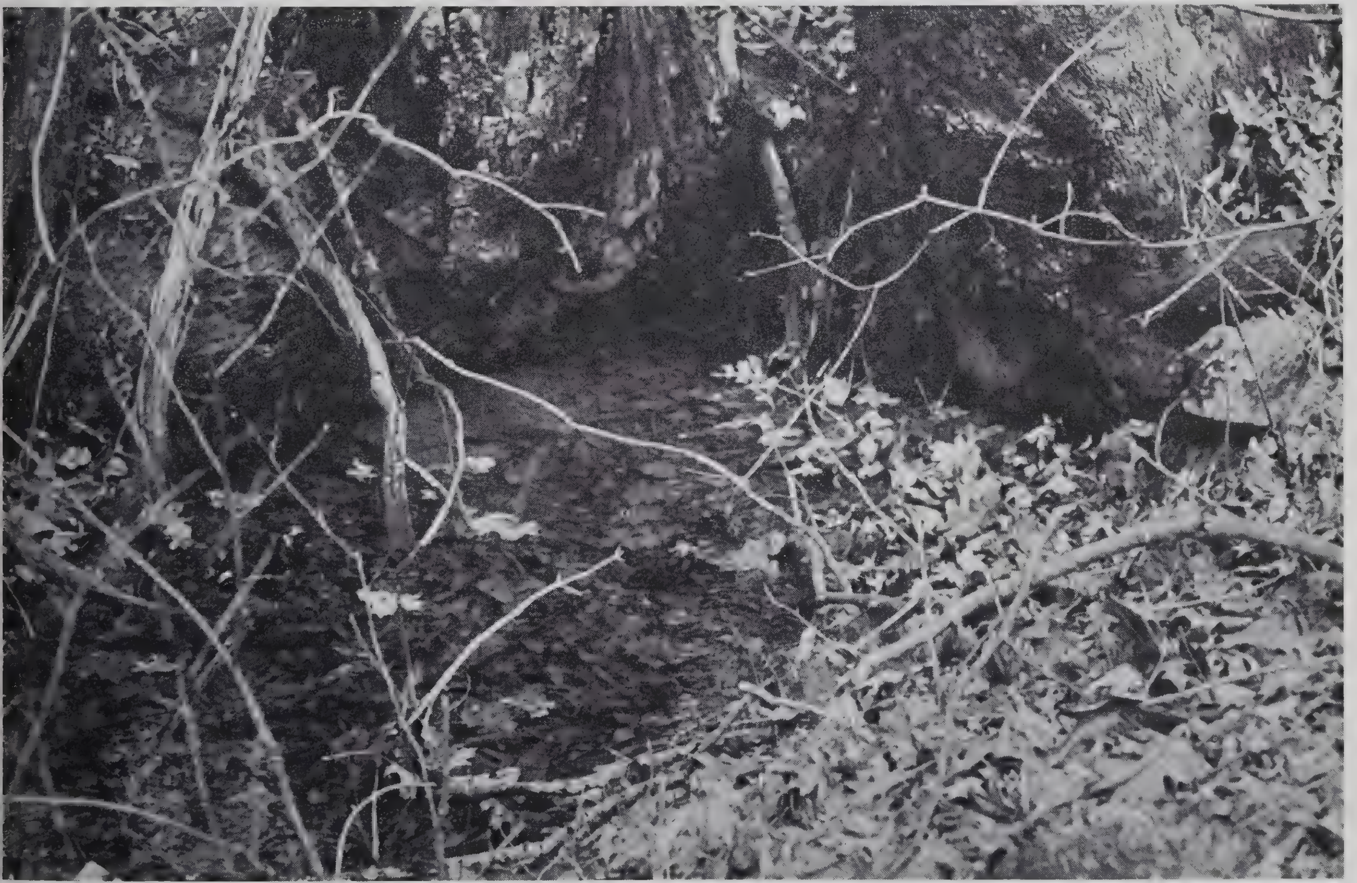

Fig. 2. — Spring along Big Creek in Hardin County, Illinois. This spring at the base of a large tree ceases to flow when the water table is very low. The first spring cavefish in Hardin County were discovered here.

fish were usually not visible during daylight hours, and at night they usually disappeared into crevices and holes when the water was disturbed or when a strong light was directed at the fish. During the day, fish could be found in spring runs by turning over rocks, but they quickly buried in gravel interstices and under other stones when uncovered. Many of the localities from which the species has been found were discovered accidentally by collectors making minnow-seine sets in spring-fed headwaters and seeps.

The species also has been taken frequently over the years in the swamp at the base of the bluffs in the LaRue-Pine Hills Ecological Area, especially during the winter months. It was believed that the swamp has springs which feed it well away from the bluffs (this is a possibility), and that the cold water in the swamp during the winter permitted the survival of the fish for longer periods of time. It is now known that the greater frequency of fish in the swamp in winter is due in part to the greater output of all springs during that season, and some fish are unable to find their way back into the spring mouth for one reason or another as will be discussed subsequently. Moreover, Weise (1957:198) found that the species has evolved a remarkable ability to tolerate without acclimation a wide temperature range, and he believed this is an important adaptation for an animal frequently swept into surface waters of relatively high temperatures.

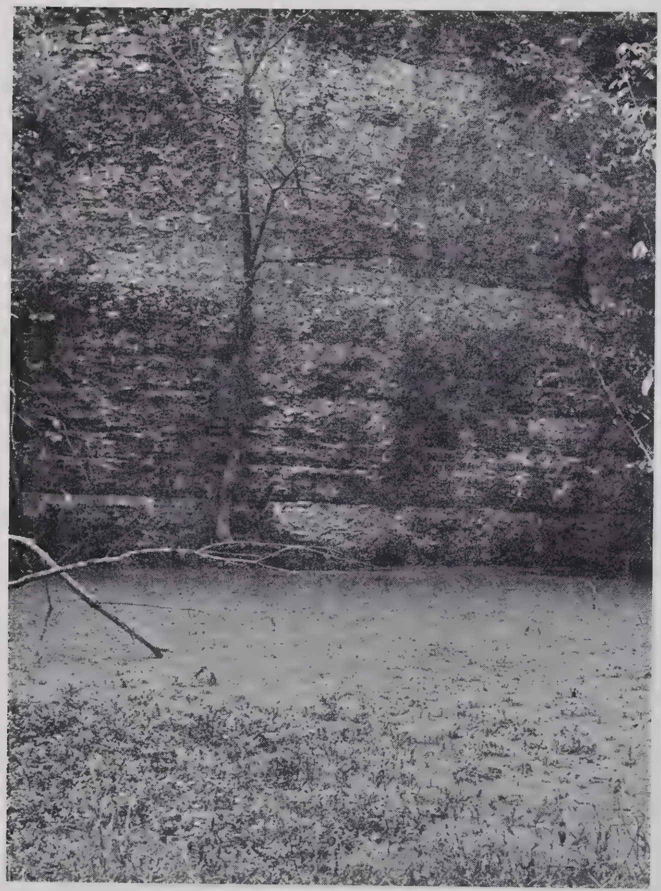

Fig. 3. — Big Spring in LaRue-Pine Hills Ecological Area, Union County, Illinois. Spring cavefish can usually be seen here, but quantitative sampling would have been impossible without destroying the character of the large spring pool. The surface is covered with duckweed.

The well-developed negative phototaxis noted above is overshadowed by a strong thigmotaxis. Weise (1957:197) found that in the absence of other forms of concealment the fish would float at the surface with the tops of their heads in contact with floating corks, and that if only lighted places of concealment were present they would utilize them in order to have some kind of body contact. If no objects were in the tank, the fish would seek the darkest corners. Hill (1969*a*:111) found that laboratory fish were attracted to objects introduced into the tanks and that cotton swabs or even strands of wire or sticks were seized by the fish but rejected if not edible. The fish depend upon taste rather than sight or olfaction to determine edibility. The fish relies on the many neuromasts on the head (Fig. 5) to locate food objects (Hill 1969*a*:111). Agitation of the water frightened the fish and they would dash about seeking concealment.

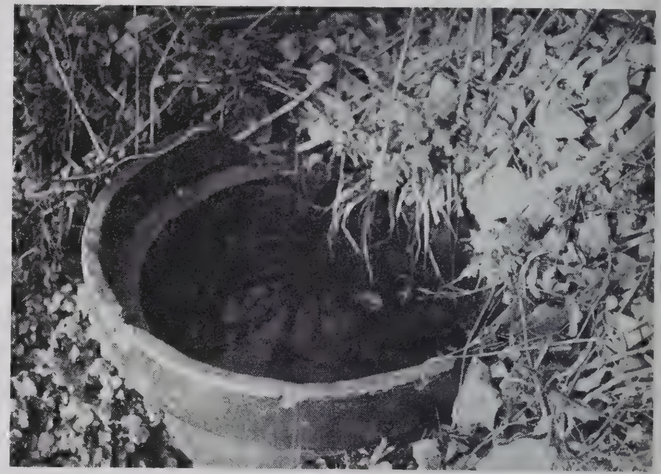

Fig. 4. — Ceramic tile at spring mouth in Union County, Illinois. When the water table is high, numerous spring cavefish can be seen at night in the tile.

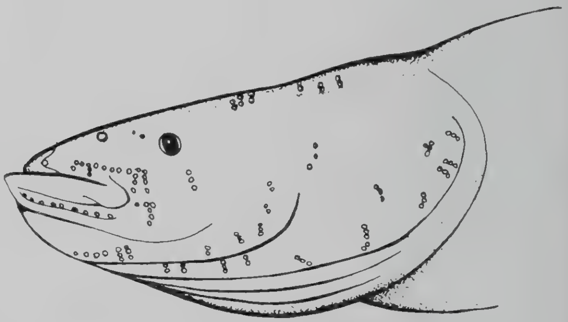

Fig. 5. — Head of spring cavefish, showing the clusters of neuromasts.

REPRODUCTION

Despite a careful search by Weise (1957) and Hill (1971), the details of reproduction in the spring cavefish remain almost unknown. Weise even attempted, but without success, stripping eggs and sperm from ripe adults into finger bowls. Our own efforts were equally unrewarding. Weise (1957:199) noted that external sexual characters were lacking, but that the fish could be sexed because the testes or ovaries could be seen through the nearly transparent body wall. We (Welch) found that ravid females were easily recognized in the fall because e large eggs were evident through the body wall, but at live fish without eggs inside them were difficult to x with any certainty because the centrally located go- ads were not that clearly visible.

Although some fish can be found at any season when e springs are flowing, and occasional gravid females uld be found "practically every month of the year" in ature (Weise 1957:200), the evidence suggests that ost fish ready for spawning disappear in late winter, resumably going underground to spawn. Captive indi- iduals held by Weise were unable to go underground nd were in ripe condition from September to March. hey refused to spawn in a simulated cave habitat in ice- oled tanks or to exhibit any prespawning behavior. A 6.8-mm (standard length) female with eggs was found June by us (Welch), and it is assumed that it had iled to go underground and would likely soon resorb s eggs. Hill (1971:13–14) found cave specimens barely ver 4 mm in total length in mid-February and noted at the first fry appear above ground while the breeding dults are still underground.

Weise (1957:199) found that in five females over 43 m (total length) the ripe ovaries contained 80, 95, 101, 02, and 285 eggs and that eggs averaged 0.25 mm in iameter in September but 1.5–2.0 mm at near maturity. ur own observations suggest that spawning probably kes place underground between January and April be- use this is the period when part of the population in e springs disappears.

Hill (1971:13–14) studied development of squama- on and pigmentation and found that scale primordia rst appear (on the sides of the caudal peduncle and a ort distance forward in the lateral-line area) at ap- roximately 6 weeks of age and that squamation and attern are well developed by 11 or 12 weeks of age.

Growth in our recaptures was erratic and inconsistent, arying with the spring in which the fish were found. ome showed almost no growth during summer and fall, ut in general the overall growth was estimated to be 10– 0 mm per year. Most authors have assumed 3-year asses; young of the year, 1+ year old, and 2+ year old sh, and probably most individuals do not live more than years. However, occasionally an individual is found at is strikingly larger than the average adult, and it is ossible that a few live 3 years and attain standard ngths of more than 70 mm. The fish appeared to be xually mature in their second year. The details of awning are wholly unknown and, while some investiga- rs suspect that the adult may carry eggs in its mouth s does the related *Amblyopsis spelaea,* they have avoided aking the statement in the absence of evidence except r the anterior location of the genital pore.

FOOD HABITS

The spring cavefish in Union County, Illinois, feed lmost exclusively on *Gammarus* according to Forbes & ichardson (1908:219), Layne & Thompson (1952:39), Veise (1957:198), and Gunning & Lewis (1955:556). Veise (1957) identified the species as *G. troglophilus* ubricht & Mackin, an amphipod that is not known to ccur at spring cavefish localities other than in southwestern Illinois. Other items found in stomachs included insect remnants and detritus (Gunning & Lewis 1955) and one *Asellus* (Weise 1957), but Weise found that captive fish refused *Asellus* as well as everything but *Gammarus.*

In Kentucky the food habits are quite different. Hill (1969*a*), who examined nearly 4,000 specimens, compared stomach contents of surface-dwelling fish with those from within caves. He found that surface fish take mostly chironomids but also small numbers of copepods, oligochaetes, nematodes, and ostracods, whereas adult and half-grown fish from caves feed almost solely on other spring cavefish. The cannibalism thus provides a source of food supply in an environment where food is extremely limited, but a large proportion of the young in caves contained no food at all or at best small numbers of nematodes and copepods. Conceivably small fish may be forced to seek an epigean food source and thus be more frequently encountered in springs than in underground streams.

DISTRIBUTION

The spring cavefish occurs from south-central Tennessee (near the Alabama state line) northward into central and western Kentucky, and westward across the Shawnee Hills of southern Illinois to Scott County, Missouri (Fig. 6). Its range was long believed to be disjunct, consisting of Illinois, Kentucky, and Tennessee populations, but recent collections from geographically intermediate areas suggest that it is more likely continuous. The counties from which it is known and the documentation for the distributional data are tabulated below, although no attempt has been made to canvass all museum collections for their holdings of the spring cavefish. Weise (1957:196) attempted to introduce 36 individuals in a cold-water cave spring in Adams County, Illinois, nearly 200 miles northward. None was ever seen again and they were presumably washed out into the open.

Missouri

Scott County: 1 spring (Pflieger 1975:224 and personal communication)

Illinois

Jackson County: 1 spring (sight record, Welch)
Johnson County: 1 spring (INHS)
Hardin County: 2 springs (INHS), 1 cave (sight record, Webb)
Pope County: 1 cave (Forbes & Richardson 1908: 219)
Union County: 1 cave, many springs (numerous museum collections)

Kentucky

Edmonson County: Mammoth Cave (Clay 1975: 241), 2 springs (Woods & Inger 1957:240)
Livingston County: 2 springs (INHS)
Logan County: 2 springs (EKU)
Lyon County: 2 springs (KFW)
Todd County: 1 spring (INHS)
Trigg County: 2 springs (MSU)
Warren County: 1 cave (Hill 1971:13) and ? springs (UMMZ), (UL)

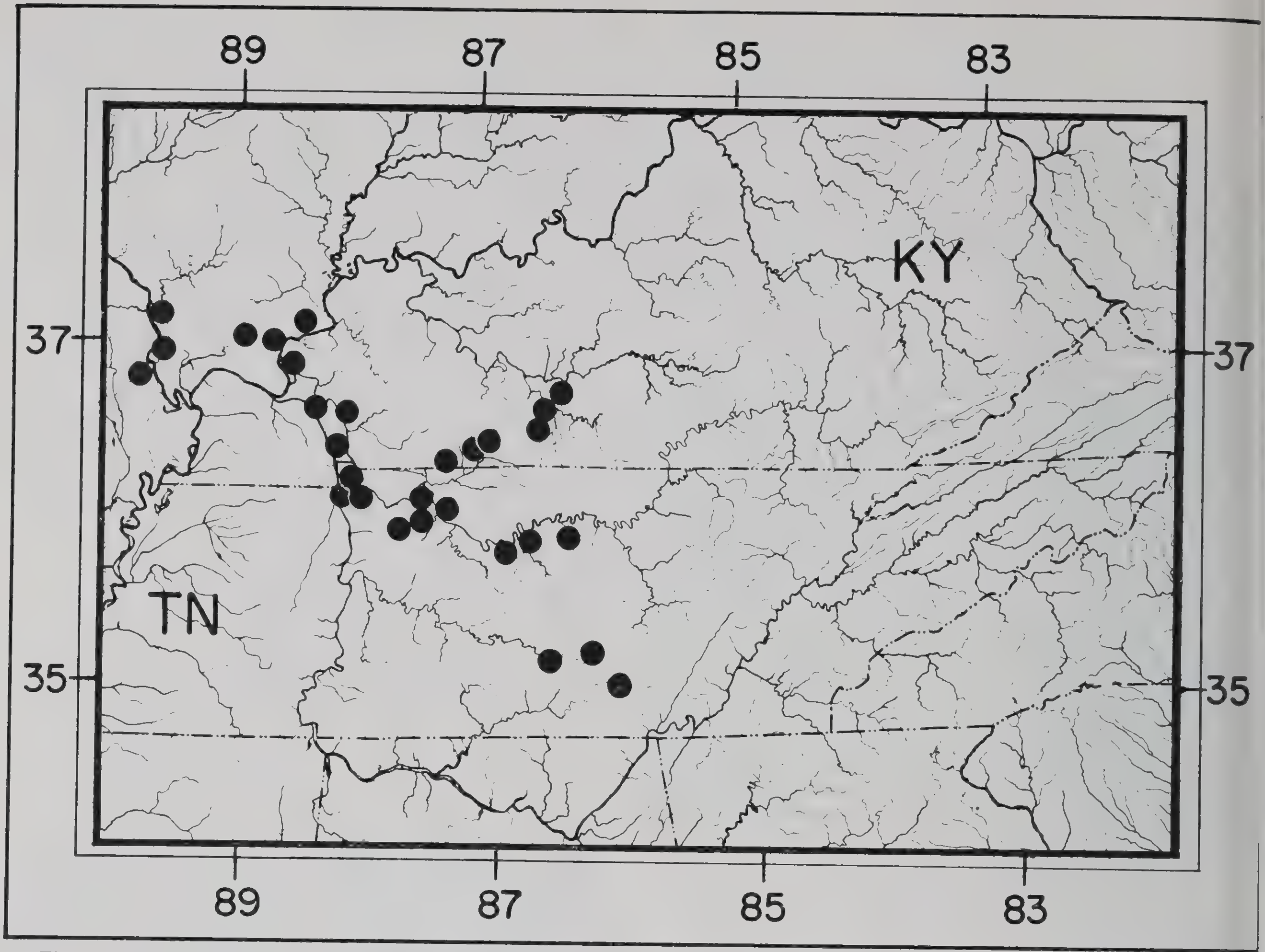

Fig. 6. — Known distribution of the spring cavefish. Sometimes a symbol represents several different springs containing the specie

Tennessee

Bedford County: 1 spring (UT)
Coffee County: ? springs (UA), (UT), (UO), (UTULSAC)
Davidson County: 2 springs (USNM)
Dickson County: 1 cave (UMMZ)
Franklin County: 1 spring (UA)
Montgomery County: ? springs (UT), (NLU), (INHS)
Stewart County: 4 springs (MSU), (UMMZ), (NLU), (INHS)
Wilson County: 1 well (Putnam 1872:22, type-locality)

POPULATION ESTIMATES

Throughout most of its range the spring cavefish is rare to uncommon and easily overlooked because of its nocturnal and secretive habits. An exception is a large spring at Rich Pond near Bowling Green, Warren County, Kentucky, where it appears to be incredibly abundant. Many museum collections have specimens from this spring (one major museum has a series of more than 1,000 specimens), and staff and students at the University of Louisville and elsewhere have collected hundreds of specimens of the species at this locality.

Elsewhere in Kentucky and Tennessee, the species is erratic in distribution and represented by a few individuals to small series. In Missouri, it has recently been discovered by Eugene McDonald (Pflieger 1975:224) and it is almost certain that the Department of Consei vation in that state will soon place the species on th list of protected species.

The species is well known from the LaRue-Pine Hil Area in southwestern Illinois, and many museum collec tions have holdings of a few specimens from that localit In fact, it was the heavy collecting pressure that precip tated the concern over the status of the population an its chances for survival. The spring cavefish was known t occur in five different springs along the bluff, where i was generally quite vulnerable to dipnetting, as well a in the adjacent swamp. Outside the Ecological Area i was known from Cave Spring Cave, a cave in Pop County, and from springs near McClure on the Union Alexander County line. A search for additional spring that might harbor the fish was begun and resulted in th discovery of three more springs that contained fish withi the Ecological Area, one in adjacent Jackson Count one in Johnson County, and two springs and a cave i Hardin County.

A total of 180 fish from 10 springs in Union Count was dipnetted and marked in 1973, and recaptures wer made in 7 of the springs. Marking was accomplished b means of an injection technique utilizing different color of printer's numbering ink. Fish were marked distinc tively so that it would be known if they had emerge from a spring other than where initially found. Befor he fish were marked, they were anesthetized with 0.05 ercent solution of MS222. Standard length was meaured with a dial caliper. The fish were placed on a wet owel and marked by an injection at a combination of pecific points along the back. The needle was inserted nder the skin about 3 mm anteriad and the dot of ink laced in the subcutaneous fascia with care being taken o avoid muscle damage. A glass tuberculin syringe with No. 23 or 25G needle was used. After marking, the sh were placed in a bowl of water and allowed to reover swimming ability before being returned to the pring. No ill effects of the marking were noted.

The marking technique was developed by Slack 1955) and has been variously modified by other workers, specially at Indiana University, for studies on crayfishes Cooper & Cooper 1976:52 and *in preparation*). It conisted of using red and blue Bates and green and purple arter's numbering machine inks injected underneath the ternites and zinc white artists' oil color to lighten colors s needed. Vegetable oil (Wesson) thinned the color to consistency that would easily pass through the syringe eedle. The method had been used previously by one of s (Welch) with good success on *Amblyopsis spelaea*. No arked fish showed any sign of infection and, although he colors faded after a period of several months, the itial puncture site remained as an unpigmented tattoo hat was easily recognized.

Estimates of population size were calculated using the etersen Estimate, which makes the following assumpions:

1. Marked animals are as subject to sampling as unmarked ones.
2. Mortality and emigration (outwash) of the marked animals are the same as in unmarked ones.
3. The time between initial capture and recapture is brief enough that mortality, natality, emigration and immigration have minimal effects.
4. No marked individuals lose their identifying marks.
5. The population remains relatively stable between trapping periods.
6. Sampling is random (which is seldom possible).

Calculations were made by summing the recapture ata over a period of time and considering a collecting ample as follows:

$$N = \frac{nT}{t}$$

here: T = number of fish marked in a spring
t = number of marked individuals recaptured (summed over the collection period)
n = total number of individuals captured = number marked plus unmarked (summed over the collection period)
N = estimate of population size

Similar results were obtained when populations were alculated from a 1–2-week interval and from an interval f over 6 months, indicating that the size estimates were onsistent. However, the estimates are admittedly crude nd sketchy representing only the easily sampled springs. o our knowledge, they are the only figures available for his fish and are presented for what they are worth.

Many of the springs in the area empty into stone basins or ceramic tiles, where relatively deep, clear pools are formed. Most of these springs flow in spring runs to the bordering swamp. The spring runs contain gravel, much watercress, and varying amounts of organic matter. Some of them run under the road in culverts and drop off precipitously into pools. Fish swept into these pools are unable to get back to the spring mouths. The largest spring (Fig. 3) in the Ecological Area empties directly into a large watercress-filled pool at the base of a sheer rock bluff. It is known to have fish but could not be sampled quantitatively because of its large size and its luxuriant growth of aquatic vegetation. Springs 7 and 8 are in southern Union County near the Alexander County line. Spring 7 is excluded from the total in Table 1 because many fish are stranded in the tile near the spring mouth and were recaptured more often than if they could have freely returned underground. Thus, the estimate for that spring may be based on stranded fish only.

TABLE 1. — Summary of mark–recapture data for eight springs in western Union County and Cave Springs Cave. Many of the standard errors are quite large because of the relatively small numbers used in the calculations.

Spring	T = No. Fish Marked	Average N = Estimate of Population ± 1 S.E.	Percent Recaptured
1	15	63 ± 28	33
2	31	180 ± 123	30
3	46	302 ± 201	35
4	1	1	0
5	7	18 ± 16	29
6	12	250 ± 539	8
7[a]	56	73 ± 6	88
8	12	96 ± 180	17
Overall, excluding No. 7	124	785 ± 314	27
Cave Springs Cave[b]	?	35–45 ± ?	?

[a] Extenuating circumstances because of physical nature of spring. See text for explanation.

[b] Estimate provided by Jeffrey J. Webb of Anna, Illinois.

CONSERVATION STATUS ON THE SHAWNEE NATIONAL FOREST

In 1969 at the suggestion of one of us (Smith), the Illinois Department of Conservation nominated the spring cavefish and four other Illinois fish species as candidates for the list of protected species, and the Illinois General Assembly passed a bill affording some degree of protection from over collecting. It has since been so noted in the Illinois Fish Code. The U.S. Forest Service also placed the cavefish on the list of species that may not be taken in the Shawnee National Forest when the LaRue-Pine Hills Recreational Area was reclassified as an Ecological Area. Since that time, however, the species has been found in several new localities, including three southern Illinois counties, and thus does not appear to be in imminent danger of extirpation in Illinois.

Nevertheless, in Union County the species is quite vulnerable to dipnetting at night by collectors, and a gene pool that may consist of fewer than a thousand individuals should be watched carefully. The restrictions on taking specimens there by both the state and Forest Service are worth retaining. Even though the population is undoubtedly larger than the above estimates indicate (the largest spring in the Ecological Area could not be censused), it is still quite small compared to those of other badly decimated species.

In the highly unusual population at Rich Pond in Kentucky, natural predation on the species is seasonably heavy (J. E. Cooper, personal communication). Elsewhere in the range of the spring cavefish, it is likely slight because of its habits and habitat. Such is not surprising for a species living in a rather trophically deprived environment. Its numbers seem to be tightly regulated by the available food supply. Gunning & Lewis (1955:554) found that 2 of 30 central mudminnows, *Umbra limi,* examined at Pine Hills contained cavefish. In Illinois the spring cavefish is not known to be cannibalistic, but a few other fishes, water snakes, and aquatic birds and mammals may catch occasional cavefish. Several fish had small leeches (species not determined) attached to them, and mention has already been made of an endemic tapeworm parasite. Dr. George Garoian, parasitologist at Southern Illinois University, found that 71 percent of t fish he examined in the springs were parasitized by ta worms and "other internal parasites" (personal comm nication to Welch).

The Ecological Area receives rigorous protection fr the Forest Service, and there is now little danger of t springs and spring runs being physically destroyed. T Forest Service has been urged by us to cap the tiles w hinged lids of metal grating to further discourage t taking of fish by human collectors and natural predat

Most of the springs tested in 1973 by us (Welc through the courtesy of Dr. C. D. Baker at the Univ sity of Illinois Dixon Springs Agricultural Station, w relatively free of pollution, but two had elevated readi for ammonia and phosphate. These substances proba got into the groundwater from animal wastes and co mercial fertilizers, and they pose some threat. Anot potential threat is a periodically discussed reservoir Clear Creek on the Mississippi River floodplain. T effects of such an impoundment could be disastrous the cavefish population if the spring mouths were in dated by backflooding or if groundwater flows w disrupted and low-quality water recharge occurred.

LITERATURE CITED

Agassiz, L. 1853. Recent researches of Prof. Agassiz. American Journal of Science and Arts, 16:134–136.

Clay, W. M. 1975. The fishes of Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky.

Cooper, J. E., and M. R. Cooper. 1976. Marking crayfish for long-term ecological studies. Association of Southeastern Biologists Bulletin 23(2):52.

Eigenmann, C. H. 1909. Cave vertebrates of America. A study in degenerative evolution. Carnegie Institution of Washington Publication No. 104.

Forbes, S. A. 1881. A rare fish in Illinois. American Naturalist 15(3):232–233.

———. 1882. The blind cave fishes and their allies. American Naturalist 16(1):1–5.

———, and R. E. Richardson. [1908]. The fishes of Illinois. Illinois State Laboratory of Natural History, [Urbana].

———, and ———. 1920. The fishes of Illinois. 2nd ed. Illinois Department of Registration and Education Natural History Survey Division, [Urbana].

Gunning, G. E., and W. M. Lewis. 1955. The fish population of a spring-fed swamp in the Mississippi bottoms of southern Illinois. Ecology 36(4):552–558.

Hill, L. G. 1968. Oxygen preference in the spring cavefish, *Chologaster agassizi.* American Fisheries Society Transactions 97(4):448–454.

———. 1969*a*. Feeding and food habits of the spring cavefish, *Chologaster agassizi.* American Midland Naturalist 82(1): 110–116.

———. 1969*b*. Distributional and populational isolation of the spring cavefish, *Chologaster agassizi* (Pisces: Amblyopsidae). Oklahoma Academy of Science Proceedings 48:32–36.

———. 1971. Scale development and patterns of squamation on the spring cavefish, *Chologaster agassizi* (Amblyopsidae). Oklahoma Academy of Science Proceedings 51:13–14.

Jordan, D. S. 1929. *Forbesichthys* for *Forbesella.* Science (1803):68.

———, and B. W. Evermann. 1927. New genera and species North American fishes. California Academy of Scien Proceedings, 16(15):501–507.

———, and C. H. Gilbert. [1883]. Synopsis of the fishes North America. U.S. National Museum Bulletin 16.

Layne, J. N., and D. H. Thompson. 1952. Recent collections the amblyopsid fish *Chologaster papillifera* in Illin Copeia 1952(1):39–40.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Depa ment of Conservation.

Poulson, T. L. 1963. Cave adaptation in amblyopsid fish American Midland Naturalist 70(2):257–290.

Putnam, F. W. 1872. The blind fishes of Mammoth Cave a their allies. American Naturalist 6(1):6–30.

Rosen, D. E. 1962. Comments on the relationships of the No American cave fishes of the family Amblyopsidae. Americ Museum Novitates No. 2109.

Slack, K. V. 1955. An injection method for marking crayfi The Progressive Fish Culturist 17(1):36–38.

Weise, J. G. 1957. The spring cave-fish, *Chologaster papillifer* in Illinois. Ecology 38(2):195–204.

Whittaker, F. H., and L. G. Hill. 1968. *Proteocephalus cho gasteri* sp. n. (Cestoda: Proteocephalidae) from the spri cavefish, *Chologaster agassizi* Putnam, 1782 (Pisces: Amb opsidae) of Kentucky. Helminthological Society of Was ington Proceedings 35(1):15–18.

Woods, L. P., and R. F. Inger. 1957. The cave, spring, a swamp fishes of the family Amblyopsidae of central a eastern United States. American Midland Naturalist 58(1 232–256.

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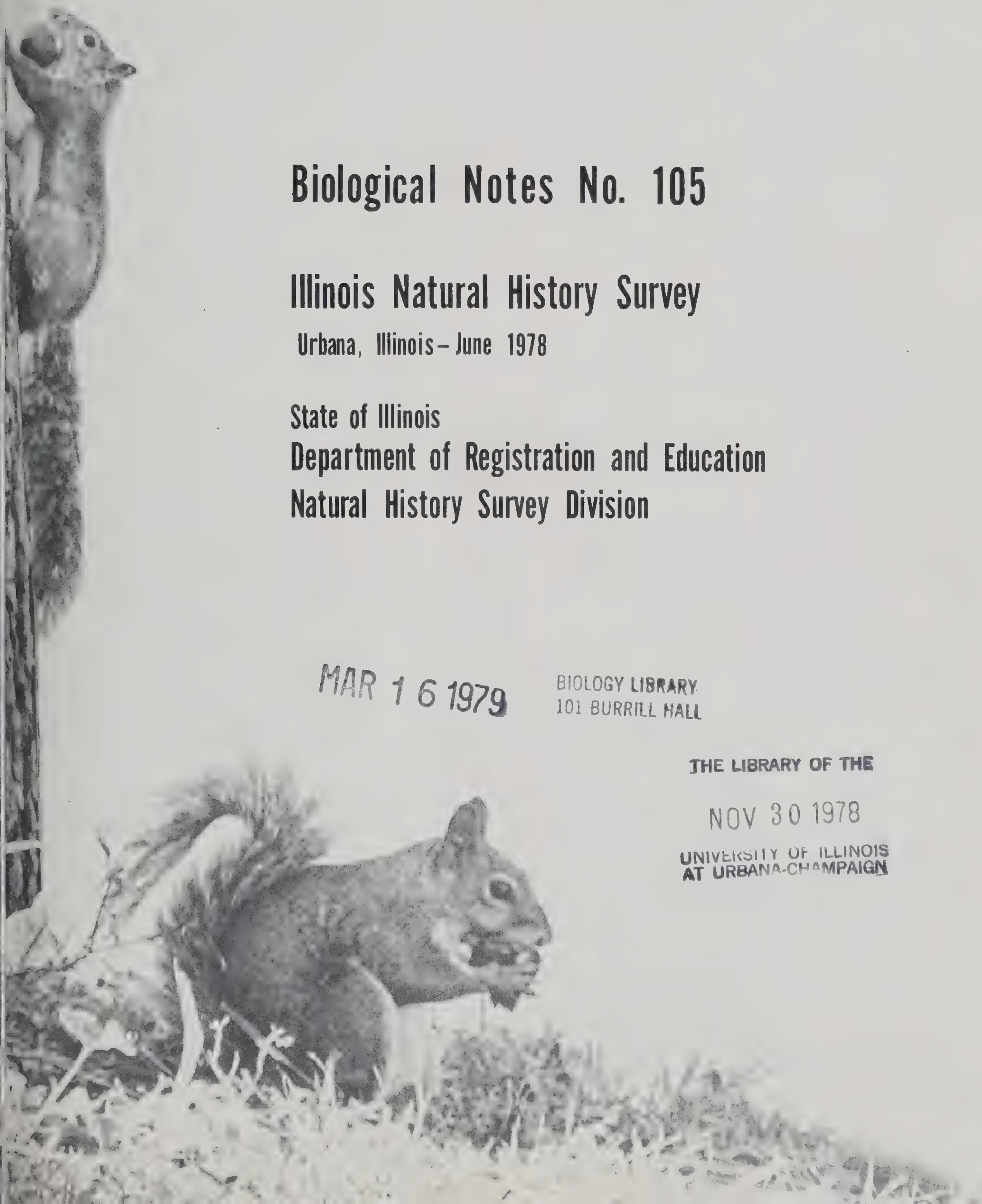
DISTRIBUTION AND ABUNDANCE OF THE GRAY SQUIRREL IN ILLINOIS

Charles M. Nixon, Stephen P. Havera, and Robert E. Greenberg



Biological Notes No. 105

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Distribution and Relative Abundance of the Gray Squirrel in Illinois

Charles M. Nixon, Stephen P. Havera, and Robert E. Greenberg

In Illinois the gray squirrel[1] apparently began declining in abundance almost as soon as the first white settlers began to clear the wilderness forests (Kennicott 1857). Gray squirrels seem to prefer extensive forests (Shelford 1963) in contrast to the woodlots and hedgerows to which fox squirrels adapted (Bakken 1952; Packard 1956). In all published comparisons of habitat preferences of these species, fox squirrels are found in open forests or in areas having a diversity of tree species of various ages (Brown & Yeager 1945; Bakken 1952; Packard 1956; Taylor 1974; and Chesemore 1975). Niche occupancy by gray and fox squirrels appears to function through habitat specialization rather than food-finding methods or dietary differences (Smith & Follmer 1972).

In Illinois extensive clearing of the virgin forests led to the virtual disappearance of gray squirrels in many of the central and northern counties (Ellsworth 1880; Hall 1916; Polson 1968). A marked reduction in overall numbers of gray squirrels also occurred throughout their entire range, particularly in the Ohio River valley, after pioneer settlement began in the 18th century (Bailey 1946; Schorger 1949).

Our objectives were (1) to determine the present distribution and relative abundance of gray squirrels throughout Illinois, (2) to determine characteristics of forest environments needed to support gray squirrels, and (3) to evaluate the future prospects of gray squirrels in the state.

We thank the many individuals who contributed information on the present status of the gray squirrel. Conservation officers, district wildlife biologists (particularly William Allen), and the district foresters of the Illinois Department of Conservation provided information from their respective areas. In Illinois Loraine Funk of Liberty, Mary Hartley and her students at Black Hawk College in Moline, and Adrian Lundeen of Fulton all helped to verify isolated populations of gray squirrels. Similar assistance was provided by Drs. Richard R. Graber, Jean W. Graber, and Carl Mohr (retired), Illinois Natural History Survey. Jack White, Director, Illinois Natural Areas Inventory, kindly allowed us access to his unpublished *Presettlement Vegetation Atlas of Illinois.* Drs. Richard and Jean Graber permitted us to use their tree inventory data from several bottomland forests in southern Illinois. We also thank the many landowners throughout central and northern Illinois who allowed us access to their forests.

We also received generous assistance from Dr. Glen C. Sanderson, Head, Section of Wildlife Research, Dr. William R. Edwards, Wildlife Specialist, both of the Illinois Natural History Survey, and Dr. Henry Shugart, Oak Ridge National Laboratory, who reviewed the manuscript. Helen C. Schultz, Section of Wildlife Research, copy-edited the first draft of the manuscript. Lloyd LeMere, Larry Farlow, and Robert M. Zewadski, Illinois Natural History Survey Technical Illustrator, Technical Photographer, and Technical Editor, respectively, provided the finished maps, figures, and final editing.

METHODS

We used county boundaries in delineating the major watersheds of Illinois (Fig. 1) because supportive data, such as the amount of forested land, human densities, and squirrel harvests, are available only by counties. We asked cooperators in each watershed to indicate townships presently "occupied" by gray squirrels. Within each township cooperators placed the gray squirrel in one of four categories of abundance: *Common*—frequently shot or seen; *Scarce*—shot or seen every year but only in low numbers; *Rare*—shot or seen infrequently (every 2 or 3 years); or *Absent.* In addition, cooperators in northern Illinois were requested to note the locations of any melanistic (black) populations of gray squirrels. We also contacted supervisors of urban parks in all the major cities of Illinois to determine the urban distribution of gray squirrels.

Maps showing the distribution of gray squirrels were prepared for each township and were compared with the locations of forested areas delineated in the most recent aerial photo-index maps available for each county (1963–1967, University of Illinois Library) and with a *Presettlement Vegetation Atlas of Illinois* (J. White, Illinois Natural Areas Inventory, unpublished data), a compilation of county maps showing the distribution of forest and prairie in each township as recorded by land surveys made between 1830 and 1860. Townships with little forest cover when first surveyed in the 19th century probably never contained more than an occasional gray squirrel in historic times.

To characterize quantitatively the range of the gray squirrel and the discriminate and significant hab-

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[1] Scientific names of plants and animals are listed in the appendix.

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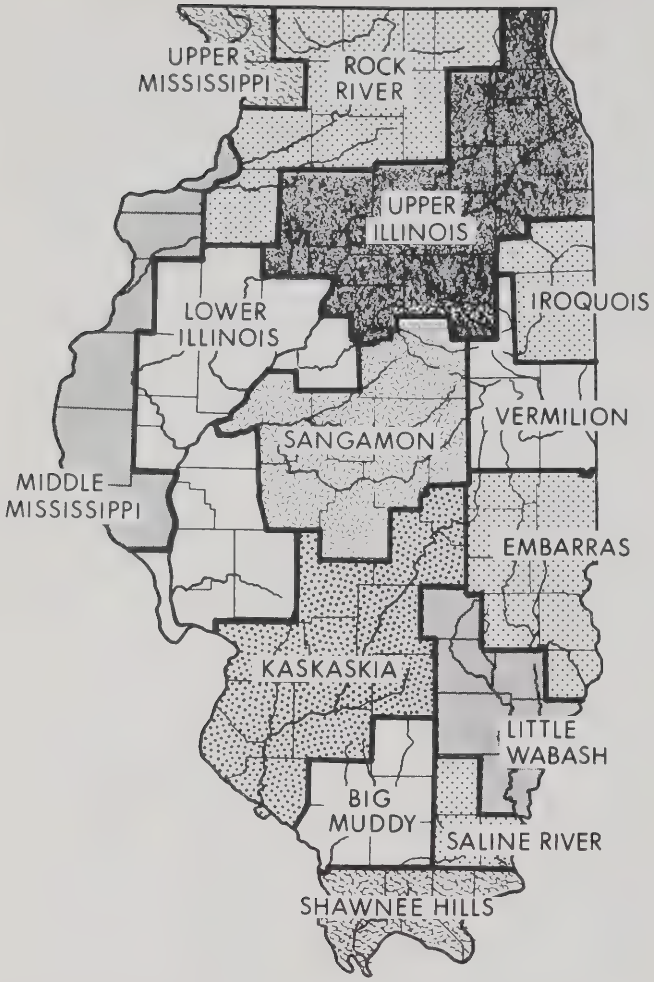

Fig. 1.—Major watersheds used to delineate the present distribution of the gray squirrel in Illinois.

itat factors, we measured forest characteristics in 12 randomly selected townships, 7 in which gray squirrels were present and 5 in which they were absent (Table 1), within eight of the major watersheds in northern and central Illinois. We randomly selected one or two sections (depending on the amount of forest available) in each of the 12 townships (Table 1). Within each selected section we then sampled vegetation in the larger (>1 ha) forest tracts, using recent aerial photos (1963–1967, University of Illinois Library). After randomly selecting a compass bearing for each tract, we extended a line along the bearing from the center of the tract to each edge. If the forest was only a narrow belt along a watercourse, transects were started from the nearest road and the tract was sampled using a zigzag (90° offset) pattern until all major forest types were included. Data were gathered from at least 10 plots in each tract unless a tract was too small or so nearly homogenous that fewer plots provided what we considered a representative sample.

Transects were divided into 8- × 40-m plots. Within each plot the following information was collected for trees with a dbh (diameter at breast height) greater than 12.7 cm: the number of trees of each species, the dbh and type of canopy of each tree (suppressed, codominant, dominant, or dead), and the average height of trees in the plot. Within each 8- × 40-m plot a 4- × 20-m subplot was used to sample all woody stems with diameters between 2.5 and 12.7 cm at the height of 1 m. We counted the number of individuals of each understory species and recorded the average understory height for each plot.

Using data from all 8- × 40-m plots in each tract, we calculated the relative density, frequency, basal area, and Importance Value Index (IVI)—the sum of relative frequency, density, and basal area/3 × 100—for each tree species; the average dbh of all codominant and dominant trees (trees that should produce seeds); the average dbh of all trees (an indication of the age of the forest); the average number of tree species per plot; and the density of all trees per hectare for each forest tract. Data from the 4- × 20-m subplots were used to calculate the average density of each understory species, the average number of species per plot, and the density of all woody stems per hectare for each tract sampled.

Vertical foliage distribution was measured every 5 m along each transect. Above each point the presence or absence of vegetation striking a cylinder 2.5 cm in diameter was recorded for height intervals of 0–1.5 m, 1.5–9 m, >9 m (Karr & Roth 1971; Willson 1974). The number of points with vegetation present in each height interval was used to calculate foliage height diversity with the Shannon-Wiener formula (Willson 1974). The percentage of vegetative cover was determined by summing over the three strata the percentages of points with vegetation present in each stratum (Karr 1968; Karr & Roth 1971; Willson 1974). The percentage of vegetative cover emphasizes total volume of vegetation, whereas foliage height diversity indexes only vertical distribution (Willson 1974). We also determined the number of plant species in each vegetative layer at each point. We felt that these vertical foliage variables, along with the species variables collected, would identify the vegetational characteristics important to gray squirrels (Packard 1956; Taylor 1974).

Along each transect we recorded any recent (<5 years) land treatment that might affect gray squirrels (pasturing, flooding, cutting, or burning) on a scale of 0 (no disturbance) to 4 (severe disturbance). We also tallied the number of tree cavities within each transect and noted whether the cavities could serve squirrels as all-weather refuges and nurseries or only as escape cover.

Using the sample sections as centers, we determined the amount and distribution of all tracts of forest for 9-square-mile areas (23.31 km²). For each area we then calculated the total number of forest tracts, the average size of these tracts, the total amount of for-

TABLE 1.—Locations of forest stands sampled and numbers of 8- × 40-m transects taken in each township and section.

Watershed	County	Township	Gray Squirrel Abundance	Site	Section Number	Number of Forest Tracts Sampled	Number of 8- × 40-m Transects Taken
Upper Mississippi	Jo Daviess	Guilford	Common	Upland	29	5	57
Rock River	Winnebago	Shirland	Common	Upland	3	1	11
				Upland	27	2	20
	De Kalb	Somonauk	Absent	Upland	34	2	9
				Bottom	34	1	7
				Upland	4	2	17
Upper Illinois	Woodford	Partridge	Common	Upland	35	1	15
				Upland	27	2	25
	Livingston	Union	Absent	Bottom	2	1	9
				Bottom	23	1	10
Lower Illinois	Schuyler	Rushville	Common	Upland	3	1	20
				Upland	8	2	20
Middle Mississippi	Henderson	Bald Bluff	Common	Bottom	11	1	20
Sangamon	Mason	Lynchburg	Common	Upland	20	1	10
				Bottom	28	2	20
				Upland	28	1	10
	Piatt	Goose Creek	Absent	Bottom	36	3	20
				Upland	36	3	48
				Upland	21	1	11
Embarras	Edgar	Prairie	Absent	Upland	19	1	10
				Bottom	19	1	7
				Upland	19A	6	63
Vermilion	Vermilion	Grant	Absent	Bottom	18	1	10
				Upland	3	2	15
		McKendree	Common	Upland	14	1	10
Total						*45*	*474*
All watersheds			Common	Upland		17	198
				Bottom		3	40
						20	*238*
			Absent	Upland		17	173
				Bottom		8	63
						25	*236*

est, and the percentage of the total area in forest.

In our analysis of forest characteristics, we used a stepwise discriminant function program to evaluate possible differences in habitat composition and structure between areas where gray squirrels were absent and areas where they were present.

Finally, we must inject a cautionary word about interpreting our maps of the distribution of gray squirrels in Illinois. The gray squirrel is a hardy, adaptable, and mobile species. Individual squirrels will often move long distances and appear in unexpected places. Where possible, we attempted to limit the occupied range to the appropriate locality (usually a watershed) in each township. In some townships such detail was not possible, and although we may show gray squirrels present in the entire area, they may be present in only a portion of the township. Gray squirrels have also been purposely stocked in unoccupied range by private individuals. For example, a successful stocking has occurred within the past 5 years along the Sangamon drainage between White Heath and Monticello in Piatt County.

HISTORY OF THE GRAY SQUIRREL IN ILLINOIS

Archeological Evidence

Tree squirrels (Sciuridae) have been present in North America at least since the Miocene (29 million years B.P.). Several species of tree squirrels are known from the early Miocene, particularly from the northern Great Basin of the western United States, which was well forested at that time (Black 1963). By this era at least nine genera of sciurids had evolved, but the place of origin for the species found in the New World in the early Pleistocene (1 million years B.P.) deposits is not known. Fossil records of the sciurids are scarce because fossils of forest-dwelling animals are usually rare (Black 1963).

Modern species of squirrels may have evolved independently in the Palearctic and Nearctic regions and migrated back and forth across the Bering land bridge (Black 1972). However, at least during the late Pleistocene, evidence shows that there was no forest cover across the Bering land bridge, the only probable route of invasion from the Palearctic to the Nearctic regions (Hopkins 1959).

During the Pleistocene four major ice advances (Nebraskan, Kansan, Illinoian, and Wisconsinan) affected Illinois. The Illinoian glaciation (100,000 years B.P.) covered nearly all of Illinois except for the southernmost 48 km and small areas in the southwest and northwest. Whether an environment suitable for gray squirrels existed anywhere in Illinois during the period of maximum glaciation is not known because no fossil records of tree squirrels from southern Illinois exist for this period. Certainly by the close of the last advance of glacial ice, the Valders substage of the Wisconsinan glaciation (14,000–11,000 years B.P.), tree squirrels were present in southern Illinois. Bones of gray and fox squirrels were found in a midden at the Modoc Rock Shelter Site located adjacent to the Mississippi River in western Randolph County (Parmalee 1959). Occupancy of the site by Paleo-Indian and archaic peoples spans some 6,000 years (10,000–4,000 years B.P.), and squirrel bones were found in small numbers throughout the midden.

Brown & Cleland (1968: 119), after reviewing pollen records and faunal remains from many sites in the Midwest, believe that the vegetation south of the Valders substage consisted of a mixture of plant communities reflecting many local microclimates and soil conditions. These communities were mixtures of upland spruce-fir, swamp coniferous forest, oak groves, and mixed hardwoods (Brown & Cleland 1968: 119). These last two forest types should have provided suitable habitat for gray squirrels. At Peccary Cave in northern Arkansas, fox squirrel bones were found contemporary with those of the yellow-cheeked vole, a species now restricted to the taiga of northwest Canada. This finding suggests that a mosaic of habitats containing both northern coniferous and deciduous elements was present in the Mississippi Valley in the early postglacial period (Hallberg et al. 1974). Pollen profiles from Illinois bogs show an early postglacial dominance of spruce-fir followed by a rapid increase in deciduous trees among which the oaks were prominent (Geis & Boggess 1968). A pollen profile from north-central Iowa showed spruce-fir dominance at 11,725 years B.P. (climate, cool-moist), deciduous forest dominant at 8,140 years B.P. (warm-dry), and prairie grasses dominant at 6,575 years B.P. (warmer-dry) (Geis & Boggess 1968). If we assume that a similar sequence of vegetational changes occurred in Illinois, there would have been concurrent changes in the distribution and abundance of gray squirrels. However, no fossil records exist for most of the postglacial period. Gray squirrels do not occupy spruce-fir forests (they were replaced by the red squirrel in the New World and the European red squirrel in th Old World), but they are found in most of the northern deciduous forests, even those with large amount of pine (Jackson 1940). The period between the retreat of glacial ice (11,000 years B.P.) and the sprea of prairie grasses into the area (6,000 years B.P.) ma have included the maximum distribution and abundance of gray squirrels during the past 12,000 year in what is now Illinois.

With the climatic change favorable to grasses, th deciduous forests began to retreat to refugia in northern and southern Illinois. Gray squirrels may hav been forced out of much of the prairie peninsula i northern and central Illinois. The possible relativ isolation of populations of gray squirrels, caused b the advancing prairie, may have resulted in limite subspeciation of the gray squirrel in the Midwest (currently, three subspecies are recognized, Barkalow & Shorten 1973).

As the climate changed toward the cooler, mor humid conditions typical of historic times, trees bega to encroach upon the prairie peninsula. Prairi vegetation was, however, often difficult to dislodg because of microclimates that favored grasses, th presence of a high water table, and frequent fires Oaks and hickories were often the first to invade at least on the steeper sites (Geis & Boggess 1968) As these pioneer tree species cooled and shaded th prairie, genera of mesic trees, such as *Acer, Ulmus* and *Tilia,* invaded the stands. Soil analyses show that forests now occupy soils developed under prairi grasses along most prairie-forest borders in Illinoi (Fehrenbacher et al. 1968).

Accumulations of bones, whether from natural entrapment or from middens left by man, shed som light on the composition and distribution of faun prior to historical records. However, interpretatio of the data must be qualified because of known triba taboos against consumption of certain species, th availability and abundance of each species aroun the campsites, the relative preservation of the bone after use, and the completeness of bone recover (Parmalee 1968). The tribes inhabiting Illinois apparently had no taboos against eating squirrels, bu their use of squirrels as food seems to have bee negligible (Munson et al. 1971).

Bones of gray squirrels have been identified a several archeological sites in Illinois (Table 2). A only one site (Cahokian Site, Madison County) wer squirrel remains abundant, ranking second to thos of white-tailed deer. At most sites squirrels appeare to represent only an incidental addition to the India diet (Table 2).

If we assume that the differing habitat requirements of fox squirrels (open woods, forest edge) an gray squirrels (interior of extensive forest with brush understory) have changed little over the past 4,00 years, then the number of each squirrel species foun

TABLE 2.—Gray and fox squirrel bones located at archeological sites in Illinois. The percentages of gray squirrel bones are compared with recent gray-squirrel kill percentages from each county.

Watershed	County	Site	Approximate Years Site Was Occupied	Numbers of Squirrels		Gray-Squirrel Percentage	1971–1973		
				Fox	Gray		Harvest of Squirrels		Gray-Squirrel Percentage
							Fox	Gray	
Kaskaskia	Randolph	Modoc[a]	11,000–5000 B.P.	22	17	43.6	306	300	49.5
Embarras	Crawford	Riverton[b]	1600–1169 B.C.	3	76	96.2	114	27	19.1
	Crawford	Swan Island[b]	1600–1169 B.C.	0	40	100.0	114	27	19.1
	Lawrence	Robeson[b]	1600–1169 B.C.	1	7	87.5	49	24	32.9
Lower Illinois	Greene	Apple Creek[c]	600 B.C.–1200 A.D.	2	4	66.7	413	154	27.2
Upper Illinois	Will	Fisher[d]	300–1600 A.D.	6	2	25.0	180	51	22.1
Lower Illinois	Peoria	Kingston[e]	1100–1400 A.D.	16	3	15.8	373	71	16.0
Kaskaskia	Madison	Cahokian[f]	1200–1550 A.D.	222	133	37.5	331	66	16.6
Kaskaskia	Monroe	Meyer Cave[g] (a natural trap)	5000 B.C.– present	0	5	100.0	96	104	52.0

[a] Parmalee (1959). [b] Parmalee (1969). [c] Parmalee et al. (1972). [d] Parmalee (1962*a*). [e] Parmalee (1962*b*). [f] Parmalee (1957). [g] Parmalee (1967).

at each archeological site can reveal something about the mosaic of forest and prairie surrounding the site. The preponderance of fox squirrels at sites in Peoria (Kingston Site) and Will (Fisher Site) counties suggests a habitat with more prairie than forest and with abundant edge between forest and prairie. Gray squirrels dominate in bone samples from Crawford and Lawrence counties, indicating extensive forests adjacent to these sites (Table 2). The more even mix of fox and gray squirrels from sites in Madison, Randolph, and Greene counties suggests a mosaic of dense forest and prairie in nearly equal proportions. It is interesting to compare ratios of gray and fox squirrels from these archeological sites with ratios taken from recent harvest records for the same counties (Table 2). Gray squirrels have declined drastically in abundance in Crawford County and probably in Greene County since prehistoric times but not appreciably in relation to numbers of fox squirrels in the remaining counties (Table 2).

Historical Records

The presettlement forests of Illinois supported immense numbers of gray squirrels as compared with their present abundance. Kennicott (1857: 629) provides a description of gray squirrel abundance during the early days of white settlement:

> "This is the most abundant of our American squirrels. It has a wide geographical range, and is prolific, and in many localities exists in almost incredible abundance. The immense numbers, heretofore mentioned as killed in one year for the bounty offered by Pennsylvania, was chiefly of this species. In Northern Ohio, I have seen them in such numbers as to be truly astonishing. Dr. Hoy relates that he knew a hunter in that state to kill one hundred and sixty in a day, and that, too, when they were not unusually abundant in the locality. In parts of Michigan, Illinois, Southern Wisconsin and Indiana they are no less numerous. Existing in such myriads, their depredations, of course, become, at times, a source of serious damage to the farmer. Fields of corn, and, occasionally, wheat, are much injured or entirely destroyed by them. I am informed that persons have sometimes kept watch in their fields to drive them off, and thus prevent the destruction of their whole crop. This species appears to increase in numbers, in certain districts, for a time after their settlement.
>
> "The migratory [gray] squirrel is at home both in low, heavy timber, and higher and somewhat more open woods, though it loves the heavily timbered, elevated ground best. It never frequents the outskirts of the woods, of which the fox-squirrel is so fond, and does not affect oak openings, nor the prairie groves, unless well timbered."

Patrick Shirreff was a Scot who toured North America in 1833 (Angle 1968: 134–135). Regarding the gray squirrel in Illinois, he wrote:

> ". . . In forests on the banks of the river Illinois, grey coloured squirrels were extremely numerous, and seemed actively engaged in collecting nuts, with which the ground was strewed. Near Pekin I walked a mile or two with a person returning from shooting squirrels, and who bestowed four or five on a woman who asked them for a sick boy."

In the fall of 1834 a great immigration of gray squirrels into southern Illinois began in Kentucky and was noted as far north as White County (Interstate Publishing Company 1883).

We searched some 300 histories of Illinois counties, published between 1870 and 1920, to help determine the distribution of gray squirrels during the early years of settlement, 1820–1860. Because squirrels are small animals, unimportant as food or as a menace to livestock, they are not always mentioned in a county's history. Fig. 2 shows the counties where squirrels were reported to be present. The reported presence of gray squirrels in the north-central counties of Henry, Knox, and McDonough and the central counties of De Witt, Macon, Piatt, and Christian, where they are scarce or absent today, indicates that gray squirrels were distributed in suitable habitats across much of the great prairie during the early days of pioneer settlement.

A search through the *Presettlement Vegetation Atlas of Illinois* (J. White, Illinois Natural Areas Inventory, unpublished data) suggests that there was probably sufficient forest cover to support gray squirrels in virtually every county in Illinois. Two possible exceptions may have been Ford and Livingston counties in east-central Illinois. Forest cover was scarce in these two counties in the 19th century before the osage orange was introduced for livestock fencing.

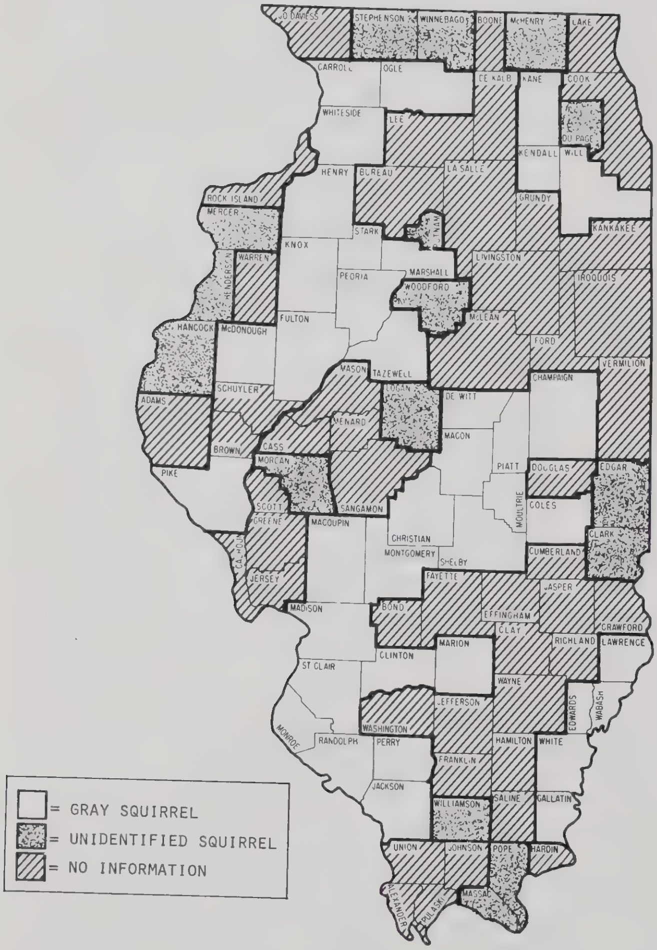

Fig. 2.—Illinois counties where gray squirrels were recorded as present during the early years of pioneer settlement, 1820–1860.

Gray squirrels were even reported to have increased for a time after settlement (Kennicott 1857) although this belief may have been the result of a more abundant human population in closer proximity to gray squirrels. It is true, however, that before the advent of cheap rail and water transportation, the native forests were a vital necessity to the pioneer. Between 1830 and 1855, forest land was valued above prairie, forest fires were controlled, forest plantations were started, and livestock was fenced out of the forests (Telford 1926). After 1855, as lumber from the great pineries of the Lake States became readily available, forests became barriers to more intensive agriculture and began to suffer the neglect and mismanagement that has continued to the present time. The presettlement Illinois forests covered about 15.25 million acres (Anderson 1970). By 1870 only 6 million acres of forest were left in Illinois and much of this acreage had been cut over, burned, and pastured one or more times. Forest acreage reached its lowest ebb in Illinois about 1914–1918 (King & Winters 1952), when little more than 3 million acres remained (Telford 1926). After 1930 forests began to increase in south-central and southern Illinois (King & Winters 1952) but continued to decline in northern Illinois (Essex & Gansner 1965). In 1962 the remaining forest land in Illinois was estimated at 3.7 million acres (Essex & Gansner 1965).

The effects of the destruction and mismanagement of forests on the abundance of gray squirrels was no less catastrophic. By the early 20th century even the casual observer could note their decreasing populations. Ellsworth (1880) reported gray squirrels as "scarce" in Marshall County, and by 1890 they were said to have been "once plentiful" in Henry County (Polson 1968). Bateman et al. (1909) reported them as "scarce" in Ogle County by 1909. At the same time fox squirrels were becoming more abundant as the large tracts of forest were destroyed and as osage orange hedgerows became widespread in the prairie counties (La Salle County, Baldwin 1877; Champaign County, Wood 1910).

By the turn of the century both species of squirrels were becoming scarce in Illinois. In 1889 the Illinois legislature set the first hunting season for squirrels from 1 June through 15 December with no daily or season bag limit. No change in regulation occurred until 1899, when the hunting season was curtailed to 1 September through 15 December, probably in response to a recognized scarcity of squirrels throughout the northeastern states (Jackson 1961). Eminent naturalists feared that both gray and fox squirrels

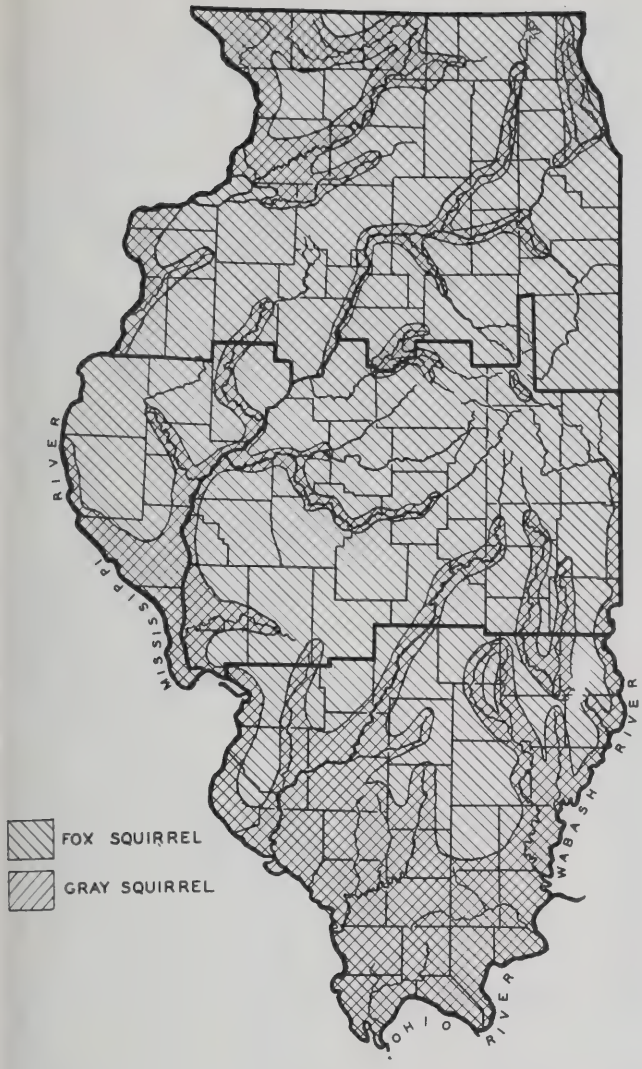

Fig.3.—Distibution of gray and fox squirrels in Illinois in 1942 (Source: Brown & Yeager 1945:454).

might be exterminated and suggested a ban on hunting throughout their range (Jackson 1961: 158). In Illinois a daily bag limit of 15 squirrels was imposed in 1915 and reduced to 10 in 1919. In 1923 three hunting zones were established for further regulation of the squirrel harvest.

In 1941–1942 Brown & Yeager (1945) attempted to map the occupied range of the gray squirrel in Illinois. The map was developed from the reported harvest of gray squirrels in each county, the distribution of forest by county in 1941–1942, and personal contacts with hunters and naturalists (Louis Brown, personal communication, 1972). Fig. 3 shows the somewhat fragmented range of gray squirrels in central and northern Illinois in 1941–1942, when they were found only along the major river valleys. Gray squirrels made up 35.3 percent of the estimated statewide squirrel kill of 1,463,305 in 1942 but constituted only 12–14 percent of the kill from central and northern Illinois (Brown & Yeager 1945: 519). By 1956–1957 gray squirrels constituted only 26 percent of 50,852 squirrels harvested throughout the state (Preno & Labisky 1971: 36). No gray squirrels were killed in two east-central Illinois counties, McLean and Iroquois, in 1956 or 1957. As we will show, Brown & Yeager undoubtedly underestimated the occupied range of the gray squirrel in some watersheds, but they also showed several occupied areas in which the gray squirrel has since been extirpated.

PRESENT DISTRIBUTION AND RELATIVE ABUNDANCE

Upper Mississippi River Region

This two-county region, comprising Carroll and Jo Daviess counties, represents a portion of the Wisconsinan driftless section of the central lowland province and lies in the extreme northwestern corner of Illinois (Fig. 4). The topography of the unglaciated western townships of both counties is one of rolling hills and great relief, particularly along interior stream canyons (Mohlenbrock 1975). Loess-capped bluffs and pallisades overlook broad terrace bottomlands along the Mississippi River. In contrast, the glaciated eastern portions of both counties are mostly flat and overlain with till 1–12 feet thick (Mohlenbrock 1975).

In 1800 the unglaciated portions of both counties were largely forested, with white and black oaks dominating the upland forests, and sugar maple, basswood, and northern red oak occurring on the more mesic lower slopes and ravines. Floodplain forests were dominated by silver maple, ashes, and elms (Mohlenbrock 1975). Jo Daviess County was about 87 percent forested and Carroll County about 24 percent forested before white settlement began after 1800 (Table 3). At present the two counties average only 12 percent forest (Table 3). This average represents a loss of 80.5 percent of their presettlement forests.

Elms, white oak, ashes, shagbark hickory, and black oak were the dominant trees in an upland forest measured in 1975 in Guilford Township, Jo Daviess County (Table 4). Many of the elms were dying, presumably because of Dutch elm disease.

To obtain a model for estimating the proportion of gray squirrels in the Upper Mississippi River Region and other watersheds in Illinois in 1800, we used regression and correlation analyses to examine the relationship between the percentage of gray squirrels in the county squirrel harvest of 1956–1957 (Y) and the amount of forest in each county in 1962 (X), using data from all 102 Illinois counties. The linear correlation of Y and X is $r = +0.82$ ($P < 0.001$), and the linear equation that best fits the regression of Y on X is $Y = 4.48 + 1.48\ X$. Assuming that this relationship between forest cover and gray squirrel abundance is an adequate representation of what existed in 1800 (present forest density does not exceed 60 percent of the land area in any county), we used the

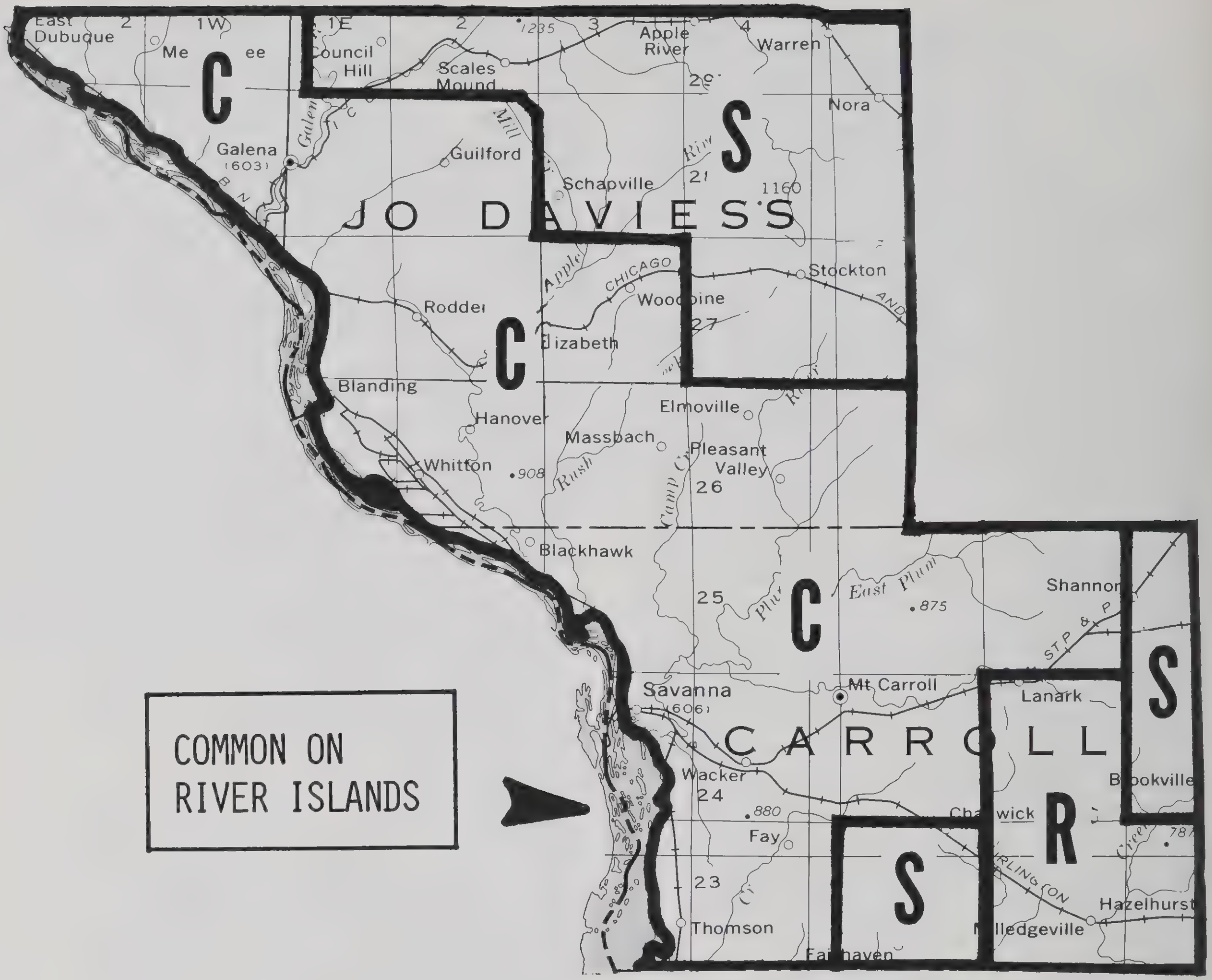

Fig. 4.—Distribution and relative abundance of the gray squirrel in the Upper Mississippi River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

regression equation to calculate the probable proportion of gray squirrels present in each watershed in 1800. The independent variable *X* (forest cover) is the acreage of forest estimated for each county in 1800 (Table 3). On this basis we estimate that 93 percent of the squirrel population in the Upper Mississippi River Region in 1800 was composed of gray squirrels, as compared with only about 35 percent in 1956–1957 (Tables 5 and 6).

Every township in the region still has gray squirrels, but they are considered scarce in the glaciated eastern townships in both counties (Fig. 4). Melanistic (black) populations of gray squirrels occur in the cities of East Dubuque and Hanover in Jo Daviess County and Mt. Carroll in Carroll County (Table 7).

Unfortunately, over half of the remaining forests in these counties are still pastured (Table 8) and suffer from overcutting and frequent wildfires. Fortunately, there has been comparatively little stream channelization and no strip-mining for coal in either county (Table 8). A comparison between the present occupied range of the gray squirrel and that shown in Fig. 3 for 1942 (Brown & Yeager 1945) indicates a considerable expansion of range in eastern Carroll County since that date. We doubt that this is true, because little change in forest cover in Carroll County has occurred since 1924 (Table 3). We believe it more likely that the 1942 survey underestimated the range of the gray squirrel in Carroll County.

Human densities remained relatively stable in this region from 1950 to 1970 (Table 9); since then, the situation has changed. Several corporations have recently purchased large tracts of land for development as sites for leisure homes. One tract of 6,800 acres in Guilford Township, Jo Daviess County, will be filled with 3,000 homesites where at present there are only a few scattered hill farms. With the extension of multilane highways west from Rockford, Illinois, we can expect more extensive real estate development in this region. As the present forests are reduced in size or cut over, gray squirrels will decline in abundance. It is fortunate that such refuges as Apple River Canyon, Tapley Woods, and Mississippi Palisades State Park and the bottomland forests in the Upper Mississippi National Wildlife Refuge will continue to offer refuge to the gray squirrel if the mature forests now present on these areas are not disturbed. Many private forests now open to squirrel hunting will probably be closed or destroyed as human densities increase. Conservation agencies must move quickly if

TABLE 3.—Forest acreage reported present at intervals since 1800 for each major watershed and each county of Illinois.

Watershed	County	1800[a]		1924[b]		1948[c]		1962[d]		Percentage of Changes 1800–1962
		Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	
Upper Mississippi	Jo Daviess	344,120	87.6	60,038	15.3	60,000	15.3	59,700	15.2	–82.6
	Carroll	70,675	23.6	24,911	8.3	22,000	7.3	21,000	7.2	–70.3
	Total or mean	*414,795*	*59.9*	*84,949*	*12.3*	*82,000*	*11.8*	*80,700*	*11.7*	*–80.5*
Rock River	Boone	70,080	38.7	5,311	2.9	6,000	3.3	3,100	1.7	–95.6
	De Kalb	30,086	7.4	5,558	1.4	5,000	1.2	5,700	1.4	–81.1
	Henry	66,841	12.6	14,240	2.7	17,000	3.2	15,700	3.0	–76.5
	Lee	29,036	6.2	10,990	2.4	9,000	1.9	10,000	2.1	–65.6
	McHenry	131,322	33.6	6,733	1.7	16,000	4.1	13,900	3.6	–89.4
	Ogle	111,655	23.0	27,757	5.7	29,000	6.0	23,000	4.7	–79.4
	Stephenson	118,250	32.5	12,020	3.3	16,000	4.0	11,600	3.2	–90.2
	Whiteside	85,126	19.3	16,653	3.8	16,000	3.6	14,300	3.2	–83.2
	Winnebago	106,900	32.1	17,877	5.4	22,000	6.6	15,500	4.7	–85.5
	Total or mean	*749,296*	*20.8*	*117,139*	*3.3*	*136,000*	*3.8*	*112,800*	*3.1*	*–84.9*
Upper Illinois	Bureau	90,197	16.2	33,973	6.1	35,000	6.3	25,600	4.6	–71.6
	Cook	70,060	11.5	23,885	3.9	30,000	4.9	28,400	4.7	–59.5
	Du Page	48,839	23.1	9,816	4.6	11,000	5.2	10,500	5.0	–78.5
	Grundy	11,379	4.1	8,837	3.2	10,000	3.6	11,200	4.1	–1.6
	Kane	100,810	30.5	8,686	2.6	10,000	3.0	8,900	2.7	–91.2
	Kendall	22,563	11.0	8,842	4.3	8,000	3.9	4,500	2.2	–80.1
	Livingston	14,710	2.2	6,400	0.9	9,000	1.3	5,300	0.8	–64.0
	Lake	154,507	52.8	19,349	6.6	20,000	6.8	13,900	4.8	–91.0
	La Salle	93,408	12.7	28,905	3.9	26,000	3.5	31,700	4.3	–66.1
	Marshall	52,935	20.9	26,552	10.5	28,000	11.1	23,400	9.3	–55.8
	Putnam	29,603	27.9	19,247	18.1	18,000	16.9	12,800	12.1	–56.8
	Stark	27,161	14.6	6,749	3.6	6,000	3.2	5,000	2.7	–81.6
	Will	53,818	10.0	19,878	3.7	23,000	4.3	20,300	3.8	–62.3
	Woodford	79,014	23.0	36,697	10.7	30,000	8.7	20,600	6.0	–73.9
	Total or mean	*849,004*	*16.0*	*257,816*	*4.8*	*264,000*	*5.0*	*222,100*	*4.2*	*–73.8*
Lower Illinois	Brown	156,000	79.4	15,015	7.6	42,000	21.4	38,200	19.4	–75.5
	Calhoun	125,843	75.9	39,367	23.7	72,000	43.4	60,700	36.6	–51.8
	Cass	96,090	40.6	32,693	13.8	46,000	19.4	32,000	15.5	–66.7
	Fulton	326,906	58.4	70,449	12.6	96,000	17.2	88,600	15.8	–72.9
	Greene	244,380	64.6	33,909	9.8	54,000	15.5	54,800	15.8	–75.6
	Jersey	180,950	75.6	47,070	19.7	66,000	27.6	55,600	23.2	–69.3
	Knox	152,422	32.7	36,265	7.8	44,000	9.4	46,500	10.0	–69.5
	Macoupin	303,481	54.4	60,936	10.9	95,000	17.0	83,100	14.9	–72.6
	McDonough	119,001	31.9	22,460	6.1	40,000	10.7	26,200	7.0	–77.9
	Morgan	179,692	49.7	14,666	4.1	30,000	8.3	26,100	7.2	–85.5
	Peoria	195,923	49.1	50,050	12.5	52,000	13.0	39,200	9.8	–79.9
	Schuyler	183,040	65.9	37,566	13.5	69,000	24.8	58,600	21.1	–67.9
	Scott	102,550	63.9	10,772	6.7	21,000	13.1	19,000	11.9	–81.4
	Tazewell	109,542	26.2	44,967	10.8	38,000	9.1	23,400	5.6	–78.6
	Warren	68,590	19.8	17,299	5.0	25,000	7.2	19,600	5.7	–71.4
	Total or mean	*2,544,410*	*49.4*	*533,484*	*10.4*	*790,000*	*15.5*	*671,700*	*13.2*	*–73.4*
Middle Mississippi	Adams	327,654	59.1	37,871	6.8	93,000	16.8	68,900	12.4	–79.0
	Hancock	224,027	43.9	34,000	6.7	46,000	9.0	49,400	9.7	–78.0
	Henderson	89,390	36.7	23,271	9.5	35,000	14.4	28,600	11.7	–68.0
	Mercer	121,536	34.2	27,123	7.6	28,000	7.9	24,300	6.8	–80.0
	Pike	329,120	62.0	33,510	6.3	97,000	18.3	72,800	13.7	–77.9
	Rock Island	136,216	50.7	35,479	13.2	34,000	12.6	29,500	11.0	–78.3
	Total or mean	*1,227,943*	*49.8*	*191,254*	*7.8*	*333,000*	*13.5*	*273,500*	*11.1*	*–77.7*
Sangamon	Christian	58,810	12.9	NOT AVAILABLE		13,000	2.9	14,500	3.2	–75.3
	De Witt	50,390	19.7			11,000	4.3	9,200	3.6	–81.7
	Logan	29,178	7.3			11,000	2.8	9,400	2.4	–67.8
	Macon	42,886	11.6			12,000	3.3	10,700	2.9	–75.1
	Mason	20,635	6.0			44,000	12.7	35,000	10.1	+69.6
	McLean	65,165	8.7			18,000	2.4	8,700	1.2	–86.6
	Menard	87,120	43.6			15,000	7.5	14,400	7.2	–83.5
	Piatt	16,206	5.8			7,000	2.5	4,900	1.8	–69.8
	Sangamon	110,558	19.6			24,000	4.3	23,200	4.1	–79.0
	Total or Mean	*480,948*	*13.3*			*155,000*	*4.3*	*130,000*	*3.6*	*–72.0*

TABLE 3.—Continued.

Watershed	County	1800[a]		1924[b]		1948[c]		1962[d]		Percentage of Change 1800–1962
		Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	Acres of Forest	Percent of Total County	
Kaskaskia	Bond	107,539	43.9	18,813	7.7	37,000	15.1	35,700	14.6	–66.8
	Clinton	140,538	44.1	56,032	17.6	62,000	19.5	52,100	16.3	–62.9
	Fayette	241,434	52.5	48,323	10.5	84,000	18.3	94,500	20.6	–60.9
	Madison	248,290	53.1	29,485	6.3	57,000	12.2	54,200	11.6	–78.2
	Marion	198,214	53.4	42,313	11.4	62,000	16.7	72,700	19.6	–63.3
	Monroe	177,279	72.9	57,918	23.8	58,000	23.8	52,000	21.4	–70.7
	Montgomery	151,580	33.6	46,498	10.3	46,000	10.2	48,100	10.6	–68.3
	Moultrie	26,874	12.2	2,074	0.9	8,000	3.6	10,100	4.6	–62.4
	Randolph	248,697	65.4	80,229	21.1	85,000	22.4	74,600	19.6	–70.0
	Shelby	155,350	31.4	47,944	9.7	55,000	11.1	62,800	12.7	–59.6
	St. Clair	262,227	61.2	47,945	11.2	55,000	12.8	58,300	13.6	–77.8
	Washington	174,086	48.1	51,212	14.2	63,000	17.4	51,700	14.3	–70.3
	Total or mean	*2,132,108*	*50.8*	*528,786*	*12.6*	*672,000*	*16.0*	*666,800*	*15.9*	*–68.7*
Big Muddy	Franklin	242,425	87.3	40,821	14.7	62,000	22.3	55,000	19.8	–77.3
	Jackson	301,145	78.0	92,100	23.9	123,000	31.9	134,700	34.9	–55.3
	Jefferson	326,110	88.0	37,467	10.2	61,000	16.6	65,600	17.9	–79.9
	Perry	228,510	80.6	60,804	21.4	61,000	21.5	61,100	21.6	–73.3
	Williamson	283,450	100.0	39,933	14.6	60,000	21.9	82,900	30.5	–70.8
	Total or mean	*1,381,640*	*87.0*	*271,125*	*17.1*	*367,000*	*23.1*	*399,300*	*25.1*	*–71.1*
Shawnee Hills	Alexander	121,997	85.1	43,847	30.6	67,000	46.7	67,600	47.1	–44.6
	Hardin	109,056	93.1	35,073	30.0	45,000	38.4	55,300	47.2	–49.3
	Johnson	212,060	96.0	64,778	29.3	79,000	35.8	84,000	38.0	–60.4
	Massac	143,080	90.9	31,604	20.1	44,000	28.0	42,100	26.7	–70.6
	Pope	241,560	99.1	65,259	26.8	100,000	41.0	146,500	60.1	–39.4
	Pulaski	110,310	84.5	23,532	18.0	34,000	26.0	30,600	23.4	–72.3
	Union	216,970	81.9	72,651	27.4	101,000	38.1	97,200	36.7	–55.2
	Total or mean	*1,155,033*	*90.4*	*336,744*	*26.3*	*470,000*	*36.8*	*523,300*	*40.9*	*–54.7*
Saline	Gallatin	194,130	92.5	52,833	25.2	55,000	26.2	54,900	26.2	–71.7
	Hamilton	264,880	95.1	34,830	12.5	53,000	19.0	54,400	19.5	–79.5
	Saline	247,488	100.0	34,523	14.0	43,000	17.5	51,000	20.7	–79.4
	Total or mean	*706,498*	*96.2*	*122,186*	*16.6*	*151,000*	*20.6*	*160,300*	*21.8*	*–77.3*
Little Wabash	Clay	157,796	53.1	33,478	11.3	46,000	15.5	47,100	15.9	–70.2
	Edwards	97,492	67.7	13,867	9.6	20,000	13.9	19,700	13.7	–79.8
	Effingham	127,808	41.4	29,654	9.6	47,000	15.2	54,500	17.7	–57.4
	Richland	152,700	65.5	22,456	9.6	30,000	12.9	37,600	16.1	–75.4
	Wabash	99,604	70.4	10,122	7.2	14,000	9.9	19,200	13.7	–80.7
	Wayne	308,582	67.4	69,874	15.3	74,000	16.2	71,500	15.6	–76.8
	White	188,282	58.7	19,150	6.0	30,000	9.4	36,700	11.4	–80.5
	Total or mean	*1,132,264*	*59.6*	*198,601*	*10.4*	*261,000*	*13.7*	*286,300*	*15.1*	*–74.7*
Embarras	Clark	226,980	70.2	30,617	9.5	58,000	17.9	68,500	21.2	–69.8
	Coles	107,604	33.2	32,605	10.0	23,000	7.1	21,200	6.5	–80.3
	Crawford	208,500	73.7	27,108	9.6	40,000	14.1	47,400	16.8	–77.3
	Cumberland	97,590	44.7	21,923	9.9	30,000	13.6	37,800	17.1	–61.3
	Douglas	26,206	9.7	2,559	0.9	5,000	1.9	4,700	1.7	–82.1
	Edgar	122,131	30.4	38,567	9.6	23,000	5.7	18,800	4.7	–84.6
	Jasper	134,649	42.5	29,847	9.4	36,000	11.4	44,100	13.9	–67.2
	Lawrence	188,710	78.8	24,457	10.2	34,000	14.2	43,500	18.2	–76.9
	Total or mean	*1,112,370*	*46.8*	*207,683*	*8.7*	*249,000*	*10.5*	*286,000*	*12.0*	*–74.3*
Vermilion	Champaign	32,651	5.1	6,400	1.0	7,000	1.1	5,100	0.8	–84.4
	Ford	4,000	1.3	3,068	1.0	1,000	0.3	1,200	0.4	–70.0
	Vermilion	114,548	19.9	5,652	1.0	29,000	5.0	25,000	4.4	–78.2
	Total or mean	*151,199*	*9.9*	*15,120*	*1.0*	*37,000*	*2.4*	*31,800*	*2.1*	*–79.0*
Iroquois	Iroquois	40,197	5.6	6,879	1.0	13,000	1.8	13,600	1.9	–66.2
	Kankakee	29,991	6.9	4,100	0.9	16,000	3.7	13,100	3.0	–56.3
	Total or mean	*70,188*	*6.1*	*10,979*	*1.0*	*29,000*	*2.5*	*26,700*	*2.3*	*–61.9*

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[a] Anonymous. 1947–1948. Plan for forestry in Illinois. Mimeographed. 36 p. [b] Telford (1926). [c] King & Winters (1952). [d] Esse & Gansner (1965).

they hope to acquire additional lands in this watershed, because land prices in the area are skyrocketing. Designation of the Apple River in Jo Daviess County as a "wild" or "scenic" river would help to retain the forests now extending along its banks and would provide a corridor of forest cover reaching from the Mississippi eastward to the glaciated uplands in the eastern portion of the county.

Rock River Region

The glaciated Rock River Region (Fig. 5) is an area of rolling topography mantled by a thin layer of Wisconsinan and Illinoian glacial till. Most of the soils developed from moderately thick loess, but soils along portions of the Rock River in Ogle and Lee counties developed from sandy, water-deposited material, forming sand ridges or dunes.

The Rock River Region was about 80 percent prairie in 1800 with Boone County the most forested (38.7 percent) and Lee County the least forested (6.2 percent) before settlement (Table 3). In 1962 only 112,800 acres of forest remained in the region, a decline of 85 percent since 1800 (Table 3).

A survey of an upland forest in Shirland Township, Winnebago County, where gray squirrels are abundant, showed that black oak, bur oak, white oak, elms, shagbark hickory, and black cherry were dominant species (Table 4). The small basal areas (m^2/ha) of these species reflected their generally young age (Table 4), but they are all staple food producers for squirrels. A survey of a bottomland forest in De Kalb County, where gray squirrels are absent, showed bur oak to be the most important species in the tree stratum but not the most numerous (Table 4). Successional species, silver maple, ashes, and elms, were the most abundant, reflecting past disturbances—including flooding, pasturing, and timber cutting—on forest composition and growth (Table 4).

The proportion of grays in the squirrel population in this region has declined from an estimated 35 percent in 1800 (Table 5) to 15–18 percent at present (Table 6). Three counties—Winnebago, McHenry, and Boone—contain the highest proportion of gray squirrels today (Table 6).

We found a significant increase ($P < 0.01$) in the proportion of gray squirrels in the squirrel harvests from the Rock River Region in 1971–1973 compared with the harvests of 1956-1957. We do not believe that this change indicates a recent increase in gray squirrels in the region, but rather a response to the continuing destruction of woodlots. Small woodlots, usually occupied by fox squirrels, are the first to be removed when priorities for land use change. Increases in the proportionate harvest of gray squirrels occurred in Boone, McHenry, Ogle, and Winnebago counties between 1956–1957 and 1971–1973 (Table 6). In these four counties human populations increased an average of 21 percent between 1960 and 1970 (Table 9), and forest cover declined about 24 percent between 1948 and 1962 (Table 3). The loss of small woodlots tended to restrict squirrel hunters to the larger forest tracts inhabited by both gray and fox squirrels, resulting in a proportionate increase in the gray squirrel harvest.

The same situation did not prevail in De Kalb, Lee, and Whiteside counties, where gray squirrels declined drastically in the harvests of 1971–1973 compared with those of 1956–1957 (Table 6). Today, gray squirrels commonly occur only in portions of Stephenson, northern and central Winnebago, eastern McHenry, and central Ogle counties (Fig. 5). They are absent throughout the southeast and southern portions of Lee, Whiteside, and Boone counties and from all of De Kalb County (Fig. 5). The fragmentation of the occupied range is a reflection of the small woodlots scattered throughout the basin. The only extensive forest cover is along the Rock River and its major tributaries. However, the Rock River and its major tributaries are not subject to extreme floods nor do they have extensive bottomlands where water stands for several weeks (Telford 1926). Hence, the nearby forests were cleared early during pioneer settlement, and remaining forests are restricted to narrow strips along the riverbanks or to small islands in the main river. The loss of forests in Boone County is particularly striking. This county had 70,000 acres of forest in 1800 but now has only 3,000 acres (Table 3), most of which is pastured (Table 8).

The small isolated population of gray squirrels in southern Lee County is apparently a remnant of an extensive population formerly occupying the large swamps that once extended along the Green River (Stevens 1914). The Inlet swamp covered 30,000 acres and undoubtedly contained extensive forests. This swamp was ditched and drained about 1901 (Stevens 1914).

A comparison of presently occupied range (Fig. 5) with that shown for 1942 (Fig. 3) indicates that the gray squirrel population has decreased in Whiteside County and in southwest Lee County along the Green River. Gray squirrels are no longer found along the Green or Edwards rivers in Henry County (M. Hartley, Black Hawk College, Moline, personal communication, 1974) although one farmer reported that a hunter had shot a gray squirrel in grazed upland timber in section 10 of Hanna Township in the fall of 1972. He also reported one or more melanistic squirrels (whether gray or fox squirrels is not known) from this same forest, which is located not far (<6.5 km) from occupied range along the lower Rock River and from the extensive forests along the lower Green River.

Gray squirrels are abundant in the city of Rockford, Winnebago County, and are scarce in Rochelle, Ogle County. There are apparently no melanistic populations of gray squirrels in the Rock River Region today, although Kennicott (1857) reported one lot of 50 black squirrels shot "near" the Rock River

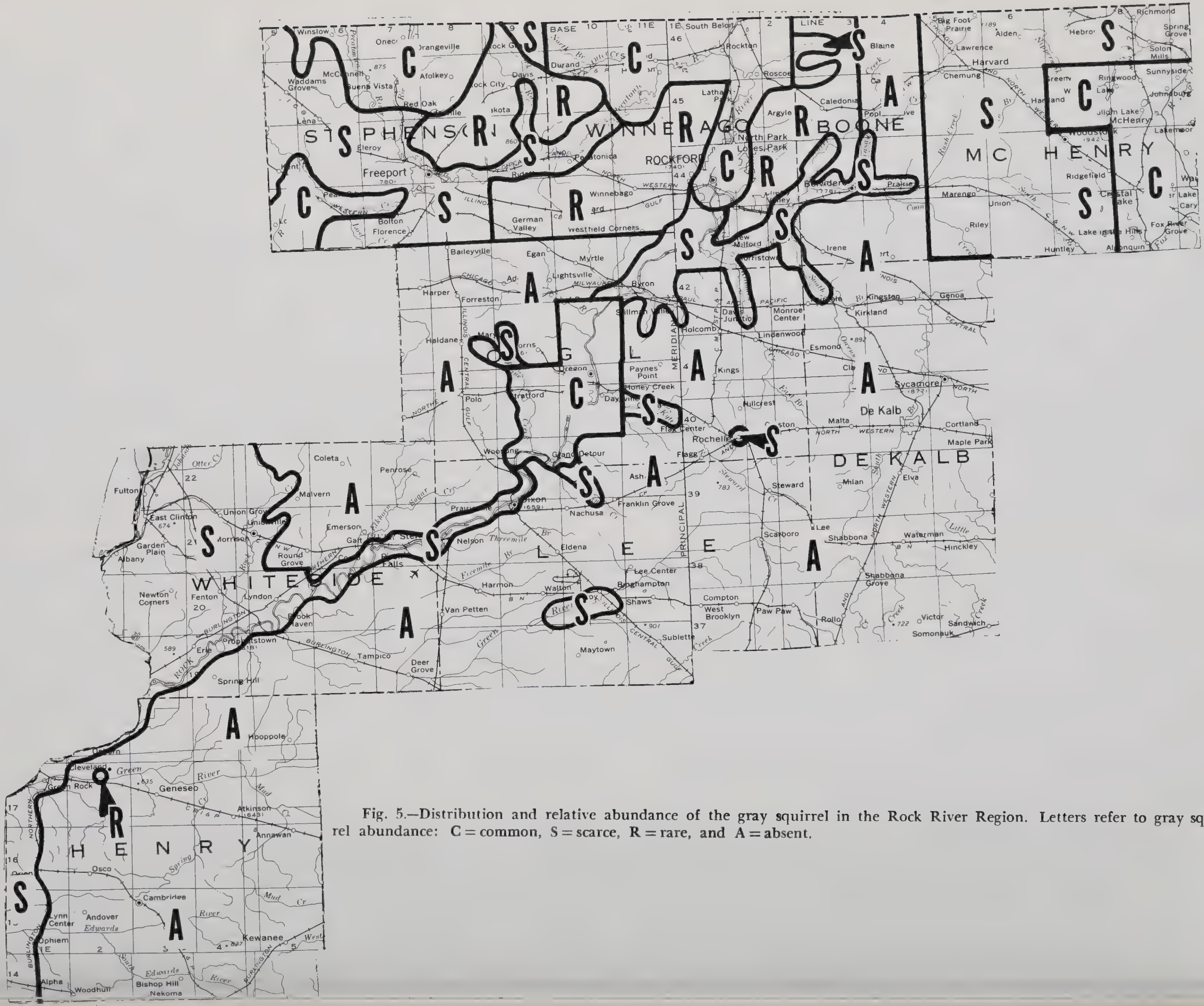


Fig. 5.—Distribution and relative abundance of the gray squirrel in the Rock River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

in the mid-19th century. As late as 1872, black squirrels were reported plentiful in the forests north of Freeport in Stephenson County (Schroger 1949: 206). Deliberate selection by hunters apparently eliminated black squirrels along the Rock River and has reduced the number of "black" gray squirrels throughout their range (Jackson 1961).

More than half the present-day forests in the Rock River basin are pastured and stream channelization has also been extensive (Table 8). Strip-mining for coal is important only in Henry County (Table 8).

Forests are declining in this watershed, particularly in Boone and Winnebago counties (Table 3), and human populations are increasing rapidly (Table 9). Between 1960 and 1970, the human population increased 32.5 percent in McHenry County, 38.6 percent and 25.2 percent in De Kalb and Boone counties, and 17.6 percent in Winnebago County. The close proximity of Rockford and Chicago makes it virtually certain that more people will move into the region either as permanent or as seasonal residents. The future of all forest-dwelling wildlife is bleak in the Rock River Region. Huntable gray squirrel populations will soon become even more difficult to find in the four northern counties as new home construction and land clearance engulf more forests. With the removal of the riparian forests, gray squirrels are even becoming scarce along such major rivers as the Pecatonica. Gray squirrels will remain in state parks and other reserves only so long as the larger tracts of forests are left undisturbed. The best remaining gray squirrel range in Ogle County is anchored in Lowden and White Pines state parks and the 2,200-acre Sinnissippi Farm, a private estate south of Oregon, where forests are managed for sustained yield.

Except in state parks and forest preserves, little can be done to retard the deleterious effects of a burgeoning human population on the natural ecosystem of the Rock River basin. The continued protection and maintenance of closed canopy old-growth hardwood forests are of prime importance on all publicly owned forests in the Rock River basin. These public forests will soon provide the primary haven for those wildlife species, like the gray squirrel, that require extensive forest habitats for survival.

Upper Illinois River Region

The Upper Illinois River Region (Fig. 6) includes the area from Lake Michigan south to the southwest corner of Woodford County. Within this region flow the Illinois River and its principal tributaries, the Fox, the Des Plaines, and the lower reaches of the Kankakee and (North) Vermilion rivers. The entire region was glaciated at least twice. The northeastern section along Lake Michigan consists of hilly moraines, deeply buried beneath glacial drift. Soils were derived from glacial drift, lake-bed sediments, beach deposits, and peat. Close to Lake Michigan are long ridges of shore-deposited sands (Mohlenbrock 1975).

South and west of Lake Michigan, the Illinois River flows through a level, poorly drained plain of relatively young drift. Moraines and other glacial landforms are common throughout this region. Soils, having developed under prairie sods growing on loess, are young and are high in organic matter (Mohlenbrock 1975).

In Woodford County we examined an upland forest where gray squirrels are common. The most important tree species was sugar maple, followed by elms, black oak, white oak, and northern red oak (Table 4). Disturbance in this forest has been limited to pasturing and timber cutting. The forest has been "high-graded" several times for timber products and is generally understocked, with many fire-scarred trees. The high incidence of oak indicates that cutting has been light enough to perpetuate these shade-tolerant species.

In contrast, a bottomland stand in Livingston County, where gray squirrels are absent, has obviously been disturbed to a much greater extent. Successional species predominate in the tree stratum, with osage orange, box elder, cottonwood, ashes, and willows the most important species (Table 4).

An average of 16 percent of the Upper Illinois River Region was forested in 1800, ranging from 53 percent in Lake County to only 2.2 percent in Livingston County (Table 3). By 1962 the forested area had declined to an average of only 4.2 percent of the total basin (Table 3). Kilburn's (1959) map, based on the original land office survey of 1834 for what are now Aurora and Batavia townships in Kane County, documents the loss of forest in the upper basin. In 1834, 7,360 acres (47.9 percent) of this 15,360-acre area were forested (Kilburn 1959). In 1964 only 345 acres (2.2 percent) (based on 7½-minute quadrangular maps—Geneva, Aurora North, Sugar Grove, and Elburn) remained forested.

The destruction of the floodplain forests along the Illinois River has been no less catastrophic. This river has a gentle fall, flows in a wide valley, and has always carried a considerable silt load—a combination conducive to the formation of numerous bottomland lakes, sloughs, and backwaters that were surrounded by forest and tended to limit agricultural development (Mills et al. 1966). However, on 1 January 1900 the Sanitary and Ship Canal was opened at Chicago, connecting the Des Plaines and Illinois rivers with Lake Michigan. The diversion of water from Lake Michigan raised the permanent water levels in the Illinois River 2–4 feet, inundated thousands of acres of bottomlands, and killed most of the timber on the newly flooded bottoms (Mills et al. 1966).

The effects of flooding on bottomland forests and on the gray squirrel have been documented by Yeager (1949) in a study of a bottomland area in Calhoun

County. Virtually all trees flooded to a depth of 20 or more inches were dead 8 years after flooding began. Pin oak, a staple food source for bottomland-dwelling squirrels, was very sensitive to a rise in the water table and died even where flooding was of short duration. Until water levels were raised, the most abundant squirrels in the bottomlands were grays; fox squirrels were confined to the pin oak ridges. The death of large tracts of flooded forest created a mosaic of living and dead timber, and fox squirrels became the more abundant species in the bottomland forests (Yeager 1949: 61).

Fig. 6 depicts the effects of this loss of timber on the distribution of the gray squirrel in the Upper Illinois River Region. From Joliet to just south of La Salle-Peru, the gray squirrel has been virtually eliminated (Fig. 6). Gray squirrels are common only in the upper and lower portions of the basin. In the upper basin, gray squirrels are primarily urban except in northern Lake County and the northwestern corner of Kane County (Fig. 6).

A comparison between the presently occupied range (Fig. 6) and that of 1942 (Fig. 3) indicates a definite reduction in the occupied range. The con-

TABLE 4.—Stand data from selected townships in each major watershed in Illinois. Trees (diameter >12.5 cm at height of 1 m) were counted on 8- × 40-m transects. Only the most important species or groups of species are included in the table.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m²/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Upper Mississippi	Jo Daviess	Guilford[a] T28N, R2E, Section 29 (Upland)	Elms	98	7.6	17.8	29.8	27.8	25.1
			White oak	37	5.2	12.4	11.2	19.1	14.2
			Ashes	39	2.4	10.8	11.8	8.9	10.5
			Shagbark hickory	27	2.3	8.5	8.3	8.3	8.4
			Black oak	21	2.6	7.7	6.5	9.4	7.9
			Black walnut	17	1.3	7.7	5.3	4.7	5.9
			Hickories (pignut, mockernut, bitternut)	18	0.6	7.7	5.5	2.3	5.1
			Basswood	10	1.6	3.1	3.2	5.7	4.0
			Black cherry	9	0.4	5.1	2.7	1.4	3.0
			Bigtooth aspen	10	0.5	3.9	3.0	1.7	2.8
			Total	*286*	*24.5*	*84.7*	*87.3*	*89.3*	*86.9*
Rock River	Winnebago	Shirland[a] T29N, R11E, Section 27; T28N, R11E, Section 3 (Upland)	Black oak	68	7.2	14.4	19.8	27.6	20.6
			Bur oak	64	5.3	18.0	18.6	20.6	19.1
			White oak	54	6.3	12.6	16.0	24.2	17.6
			Elms	65	2.5	21.6	18.9	9.7	16.7
			Shagbark hickory	28	2.0	11.7	8.3	7.5	9.2
			Black cherry	28	0.7	7.2	8.3	2.5	6.0
			Shadbush	7	0.9	5.4	2.1	3.5	3.7
			Box elder	16	0.5	1.8	4.7	1.8	2.8
			Black walnut	7	0.4	3.6	2.1	1.6	2.4
			Hickories (pignut, mockernut, bitternut)	3	0.2	1.8	0.9	0.8	1.2
			Total	*340*	*26.0*	*98.1*	*99.7*	*99.8*	*99.3*
Rock River	De Kalb	Somonauk[a] T37N, R5E, Sections 4 & 34 (Bottomland)	Bur oak	31	7.7	15.0	10.0	29.5	18.2
			Ashes	54	2.4	10.0	17.1	9.1	12.1
			Elms	52	1.4	12.0	16.5	5.3	11.3
			Silver maple	46	1.8	3.0	14.6	6.8	8.1
			Shagbark hickory	20	2.1	8.0	6.2	8.2	7.5
			White oak	10	3.0	7.0	3.1	11.4	7.2
			Black cherry	22	0.5	7.0	7.2	2.0	5.4
			Northern red oak	11	2.0	5.0	3.4	7.7	5.4
			Hawthorns	25	0.5	6.0	8.1	2.0	5.3
			Black oak	8	1.9	5.0	2.5	7.4	5.0
			Total	*279*	*23.3*	*78.0*	*88.7*	*89.4*	*85.5*

tiguous range along the Illinois and Fox rivers, as shown by Brown & Yeager (1945), no longer exists. Gray squirrels have apparently been extirpated from the Vermilion River (North) since the 1942 survey.

In the lower part of the region, the range of the gray squirrel is centered in western Woodford and Marshall counties. In Woodford County this range includes both upland and bottomland forests. Small

TABLE 4.—Continued.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m²/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Upper Illinois	Woodford	Partridge[a] T28N, R3W, Section 27; T27N, R3W, Section 35 (Upland)	Sugar maple	48	5.1	14.5	16.4	23.2	18.0
			Elms	40	2.5	12.7	13.8	11.2	12.5
			Black oak	30	2.9	10.2	10.2	13.2	11.2
			White oak	34	2.5	8.4	11.9	11.5	10.6
			Northern red oak	17	2.2	6.6	5.9	9.8	7.5
			Chinquapin oak	14	1.1	2.4	4.9	4.9	4.1
			Hickories (pignut, mockernut, bitternut)	12	0.7	4.2	4.3	3.1	3.9
			Hop hornbeam	13	0.3	5.4	4.3	1.1	3.6
			Bur oak	11	0.6	4.2	3.8	2.7	3.6
			Basswood	9	0.9	3.0	3.2	4.3	3.5
			Total	*228*	*18.8*	*71.6*	*78.7*	*85.0*	*78.5*
Upper Illinois	Livingston	Union[a] T29N, R7E, Sections 23 & 2 (Bottomland)	Osage orange	212	8.1	37.5	47.3	30.2	38.3
			Box elder	164	8.2	27.5	36.6	30.6	31.6
			Cottonwood	21	8.0	10.0	4.8	29.9	14.9
			Ashes	15	1.1	10.0	3.3	3.9	5.7
			Willows	14	0.8	5.0	3.3	2.9	3.7
			Hawthorns	15	0.5	5.0	3.3	1.8	3.4
			Crab apples	5	0.1	2.5	1.1	0.4	1.3
			Black walnut	2	0.1	2.5	0.4	0.3	1.1
			Total	*448*	*26.9*	*100.0*	*100.0*	*100.0*	*100.0*
Lower Illinois	Schuyler	Rushville[a] T2N, R2W, Section 8; T2N, R1W, Section 3 (Upland)	Sugar maple	61	6.6	13.6	21.3	28.0	21.0
			White oak	57	4.5	15.6	19.9	19.2	18.2
			Black oak	37	2.9	12.3	12.8	12.5	12.5
			Hickories (pignut, mockernut, bitternut)	38	2.3	13.0	13.4	9.6	12.0
			Elms	23	1.4	10.4	8.2	5.8	8.1
			Shagbark hickory	23	1.2	7.8	7.9	5.2	7.0
			Northern red oak	14	1.8	7.1	4.9	7.5	6.5
			Hop hornbeam	10	0.2	5.8	3.5	0.8	3.4
			Black cherry	4	0.5	2.6	1.4	2.0	2.0
			Ashes	2	0.7	1.3	0.8	2.9	1.7
			Total	*269*	*22.1*	*89.5*	*94.1*	*93.5*	*92.4*
Middle Mississippi	Henderson	Bald Bluff[a] T12N, R5W, Section 11 (Bottomland)	Silver maple	228	24.3	26.3	55.7	42.8	41.6
			Ashes	66	5.8	17.1	16.0	10.3	14.5
			Pin oak	19	7.6	9.2	4.6	13.4	9.1
			Cottonwood	16	7.0	6.6	3.8	12.4	7.6
			Dead trees	19	2.8	10.5	4.6	5.0	6.7
			Honey locust	13	3.9	7.9	3.1	6.8	5.9
			Elms	14	1.5	7.9	3.4	2.6	4.6
			River birch	16	1.9	5.3	3.8	3.3	4.1
			Sycamore	6	1.4	1.3	1.5	2.5	1.8
			Osage orange	5	0.1	2.6	1.2	0.2	1.3
			Total	*402*	*56.3*	*94.7*	*97.7*	*99.3*	*97.2*

TABLE 4.—Continued.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m^2/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Sangamon	Piatt	Goose Creek[a] T18N, R4E, Section 21; T18N, R5E, Section 36 (Bottomland)	Silver maple	348	35.7	40.0	78.1	70.9	62.9
			Honey locust	35	3.9	15.0	7.9	7.7	10.2
			Sycamore	19	9.5	5.0	4.4	18.8	9.4
			Elms	23	0.7	15.0	5.3	1.4	7.2
			Ashes	12	0.3	15.0	2.6	0.6	6.1
			Osage orange	4	0.2	5.0	0.9	0.4	2.1
			Hawthorns	4	0.1	5.0	0.8	0.1	2.0
			Total	*445*	*50.4*	*100.0*	*100.0*	*99.9*	*99.9*
		Goose Creek[a] T18N, R4E, Section 21; T18N, R5E, Section 36 (Upland)	Elms	151	5.3	19.6	35.7	21.5	25.6
			Hackberry	134	5.3	19.6	31.6	21.4	24.2
			Bur oak	30	3.3	10.9	7.0	13.3	10.4
			Honey locust	16	4.8	7.6	3.7	19.6	10.3
			Hickories (pignut, mockernut, bitternut)	31	0.9	13.0	7.4	3.9	8.1
			Black walnut	16	1.4	6.5	3.7	5.8	5.3
			Basswood	6	1.8	2.2	1.5	7.4	3.7
			Total	*384*	*22.8*	*79.4*	*90.6*	*92.9*	*87.6*
Sangamon	Mason	Lynchburg[a] T18N, R10W, Sections 28 & 20 (Bottomland)	Silver maple	163	7.1	14.3	35.6	22.6	24.2
			Cottonwood	66	12.8	14.3	14.4	41.1	23.3
			Pin oak	50	3.6	9.5	11.0	11.6	10.7
			Elms	41	1.1	14.3	8.9	3.5	8.9
			Box elder	31	1.5	7.1	6.8	4.7	6.2
			Ashes	19	0.6	9.5	4.1	1.9	5.2
			Pecan	19	1.0	7.1	4.1	3.3	4.8
			Total	*389*	*27.7*	*76.1*	*84.9*	*88.7*	*83.2*
	Mason	Lynchburg[a] Section 20 (Upland)	Black oak	97	20.4	55.5	52.5	87.4	65.2
			Blackjack oak	88	2.9	44.5	47.5	12.6	34.8
			Total	*185*	*23.3*	*100.0*	*100.0*	*100.0*	*100.0*
Kaskaskia	St. Clair	Englemann[b] T1S, R6W, Sections 23, 24, 25, & 26 (Bottomland)	Silver maple	78	6.2	13.3	19.3	23.1	18.5
			Hackberry	93	2.7	14.7	23.0	10.0	15.9
			Elms	59	2.9	15.1	14.6	11.0	13.6
			Ashes	37	2.7	7.2	7.5	8.0	7.6
			Box elder	26	0.9	7.2	6.4	3.6	5.7
			Overcup oak	15	2.2	4.3	3.8	8.1	5.4
			Big shellbark hickory	18	1.4	6.1	4.3	5.1	5.2
			Pin oak	15	2.0	4.3	3.6	7.4	5.1
			Pecan	12	1.3	4.7	2.9	4.6	4.1
			Bur oak	6	0.7	2.9	1.4	2.6	2.3
			Total	*359*	*23.0*	*79.8*	*86.8*	*83.5*	*83.4*
Kaskaskia	Shelby	Windsor[c] T11N, R4E, Section 30 (Upland)	White oak	345	11.3	11.9	53.1	52.6	39.2
			Black oak	90	3.2	10.7	13.9	14.7	13.1
			Northern red oak	64	2.6	10.7	9.9	12.0	10.9
			Hickories (pignut, mockernut, bitternut)	31	0.6	11.9	4.8	3.0	6.6
			Shagbark hickory	31	1.2	8.3	4.8	5.6	6.2
			Ashes	31	0.8	7.1	4.8	4.0	5.3
			Elms	11	0.2	8.3	1.7	1.1	3.7
			Shingle oak	10	0.4	6.0	1.5	2.1	3.2
			Black walnut	10	0.3	6.0	1.5	1.5	3.0
			Sugar maple	11	0.4	3.6	1.7	2.0	2.4
			Total	*634*	*21.0*	*84.5*	*97.7*	*98.6*	*93.6*

remnant populations of gray squirrels, holdovers from extensive populations that existed as late as 1900 along the Illinois and Kankakee rivers (Hahn 1907), persist south of Joliet and along the lower Kankakee River.

In La Salle County, gray squirrels are abundant only in Starved Rock State Park (Fig. 6) and the city

Table 4.—Continued.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m^2/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Big Muddy	Jackson	Elk[b] T7S, R1W, Sections 14, 15, 22, & 23 (Bottomland)	Pin oak	16	5.8	10.4	6.1	26.3	14.3
			Silver maple	39	2.7	8.9	14.4	12.4	11.9
			Big shellbark hickory	29	3.6	6.1	10.7	16.1	11.0
			Elms	33	1.1	12.2	12.3	4.9	9.8
			Ashes	25	1.4	10.4	9.2	6.4	8.7
			Swamp white oak	21	1.3	8.5	7.7	5.7	7.3
			Post oak	21	1.2	4.3	8.6	5.3	6.1
			Shagbark hickory	15	1.0	7.2	5.5	4.4	5.7
			Mockernut hickory	16	1.0	5.3	6.1	4.7	5.4
			Black oak	7	0.4	2.9	2.5	1.8	2.4
			Total	*222*	*19.5*	*76.2*	*83.1*	*88.0*	*82.6*
Shawnee Hills	Union[b]	(No Township) T12S, R2W, Sections 30 & 31 (Bottomland)	Silver maple	61	5.3	9.6	12.7	17.8	13.3
			Sweet gum	58	3.9	7.6	12.2	13.1	10.9
			Elms	51	3.1	11.9	10.8	10.2	10.9
			Pin oak	42	3.7	6.4	8.8	12.4	9.2
			Box elder	56	1.8	8.4	11.6	6.2	8.7
			Ashes	39	1.8	9.9	8.1	6.2	8.0
			Sugarberry	27	1.2	5.8	5.7	4.1	5.2
			Pecan	19	1.1	5.2	4.0	3.8	4.3
			Hackberry	12	0.6	4.1	2.5	1.9	2.8
			Cottonwood	10	1.2	2.3	2.1	4.1	2.8
			Total	*375*	*23.7*	*71.2*	*78.5*	*79.8*	*76.1*
Shawnee Hills	Johnson	Cache[b] Vienna T13S, R2E, Sections 30 & 31 (Bottomland)	Sweet gum	71	3.7	11.6	17.1	12.2	13.6
			Ashes	46	2.0	8.3	11.1	6.8	8.7
			Elms	29	2.3	8.8	7.1	7.7	7.9
			Swamp chestnut oak	22	2.7	6.1	5.4	8.9	6.8
			Box elder	27	1.1	3.9	6.5	3.6	4.7
			Red maple	22	1.2	4.4	5.4	4.1	4.7
			Ironwood (blue beech)	20	0.3	7.7	4.9	1.1	4.6
			Shumard's oak	7	1.9	2.2	1.6	7.3	3.7
			Tulip tree	19	1.1	2.8	4.6	3.5	3.6
			Pin oak	7	1.9	2.2	1.6	6.4	3.4
			Total	*270*	*18.2*	*58.0*	*65.3*	*61.6*	*61.7*
Shawnee Hills	Pope[c]	(No Township) T13S, R6E, Section 5 (Upland)	Northern red oak	38	7.9	11.3	12.5	33.4	19.1
			Sugar maple	90	3.2	12.0	29.9	13.8	18.6
			Hickories (pignut, mockernut, bitternut)	46	3.0	11.3	15.4	12.8	13.2
			American beech	31	2.6	9.3	10.1	11.2	10.2
			Shagbark hickory	17	1.2	8.6	5.7	5.3	6.5
			White oak	14	1.1	9.6	4.6	4.6	6.3
			Elms	22	0.7	7.6	7.2	2.8	5.9
			Tulip tree	11	1.3	4.8	3.8	5.7	4.8
			Ashes	8	0.8	4.8	2.6	3.2	3.5
			Black oak	5	0.6	3.8	1.7	2.7	2.7
			Total	*282*	*22.4*	*83.1*	*93.5*	*95.1*	*90.8*

Table 4.—Continued.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m^2/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Saline	Saline	Raleigh[b] T8S, R6E, Sections 29, 30, 32 & 33 (Bottomland)	Ashes	61	2.3	12.0	14.0	9.9	12.1
			Northern red oak	49	3.3	9.5	11.4	14.1	11.7
			Sweet gum	48	3.2	8.9	11.1	13.4	11.1
			Black oak	36	3.9	6.3	8.3	16.6	10.4
			Elms	48	0.9	13.3	11.1	3.7	9.1
			Pin oak	32	3.0	5.7	7.4	12.8	8.6
			Shagbark hickory	20	0.7	7.0	4.6	3.0	4.8
			River birch	20	0.8	2.5	4.6	3.4	3.5
			Silver maple	13	0.6	3.8	3.1	2.6	3.1
			Cherrybark oak	5	1.2	1.9	1.2	5.1	2.7
			Total	*332*	*19.9*	*70.9*	*76.8*	*84.6*	*77.1*
Little Wabash	Wabash[b]	(No Township) T2S, R13W, Section 11 (Bottomland)	Elms	83	2.5	18.7	24.3	6.6	16.5
			Hackberry	64	2.0	16.0	18.7	5.2	13.3
			Silver maple	37	4.8	8.0	10.9	12.6	10.5
			Sweet gum	17	2.8	6.7	4.9	7.5	6.4
			Box elder	24	0.7	8.0	7.0	2.0	5.7
			Bur oak	6	4.4	3.3	1.8	11.6	5.6
			Pecan	8	3.3	4.0	2.5	8.7	5.1
			Northern red oak	5	3.6	2.0	1.4	8.6	4.0
			Sugarberry	19	0.6	4.7	5.6	1.5	3.9
			Shagbark hickory	12	2.0	2.7	3.5	5.4	3.8
			Total	*275*	*26.7*	*74.1*	*80.6*	*69.7*	*74.8*
Embarras	Edgar	Prairie[a] T16N, R10W, Section 19; T16N, R11W, Section 19 (Upland)	Osage orange	78	3.6	14.1	21.5	17.0	17.6
			Black walnut	38	2.6	11.8	10.4	12.2	11.4
			Honey locust	48	2.3	10.2	13.4	10.7	11.4
			Shagbark hickory	43	2.6	9.4	11.9	12.0	11.1
			Shingle oak	22	2.4	8.2	6.1	11.1	8.4
			Elms	23	0.7	7.4	6.5	3.3	5.7
			Black cherry	14	0.8	7.8	4.0	3.6	5.1
			Black oak	12	1.8	2.0	3.5	8.5	4.7
			Hickories (pignut, mockernut, bitternut)	17	0.7	4.7	4.8	3.3	4.3
			Hackberry	9	1.0	3.5	2.4	4.8	3.6
			Total	*304*	*18.5*	*79.1*	*84.5*	*86.5*	*83.3*
Embarras	Coles	Pleasant Grove[d] T11N, R9E, Section 23 (Bottomland)	Silver maple	420	19.8	26.1	62.4	50.7	46.4
			Cottonwood	132	15.2	23.8	19.6	38.8	27.4
			Box elder	51	1.4	22.7	7.6	4.3	11.5
			Willows	52	1.5	9.0	7.6	3.7	6.8
			Red elm	7	0.1	6.8	1.0	0.3	2.7
			Total	*662*	*38.0*	*88.4*	*98.2*	*97.8*	*94.8*
Vermilion	Vermilion	Grant[a] T22N, R12W, Section 3; T23N, R11W, Section 18 (Upland)	Osage orange	221	7.2	19.2	44.1	28.9	30.8
			Shagbark hickory	63	4.8	10.1	12.5	19.4	14.0
			Box elder	64	2.1	7.1	12.7	8.4	9.4
			Hawthorns	49	0.9	13.1	9.7	3.6	8.8
			Black oak	21	3.6	7.1	4.2	14.7	8.7
			Bur oak	13	1.7	7.1	2.5	6.8	5.5
			Willows	16	0.9	2.0	3.2	4.0	3.1
			White oak	4	1.3	3.0	0.8	5.3	3.0
			Black cherry	7	0.2	6.1	1.5	0.6	2.7
			Black walnut	10	0.4	4.0	2.0	1.6	2.5
			Total	*468*	*23.1*	*78.8*	*93.2*	*93.3*	*88.5*

of Streator, southeast La Salle County (Streator Superintendent of Parks, personal communication, 1976), where Mohr (1941) reported them present in 1940.

Gray squirrels made up an estimated 28.2 percent of the squirrel population in the Upper Illinois River Region in 1800 (Table 5). In recent years gray squirrels still have constituted between 12 and 20 percent of the squirrel harvest (Table 6). Woodford, Marshall, and Lake counties contribute most of the gray squirrels to the harvest in the basin. As noted for the Rock River Region, the significant ($P < 0.01$) increase in the proportion of gray squirrels in the squirrel harvest between 1956–1957 and 1971–1973 (Table 6) is probably due to the loss of woodlots that formerly supported fox squirrels. The remaining forests, restricted to the roughest topography, are relatively large and contain proportionately more gray squirrels.

The largest concentration of melanistic gray squirrels left in Illinois is found in the Upper Illinois River Region along the shoreline of Lake Michigan from Evanston north to Zion (Table 7). Black gray squirrels have managed to survive in Illinois only where they are protected from hunting, as in urban parks or other reservations. Human settlements along Lake Michigan north of Chicago most likely progressed so rapidly (human densities increased 46 times between 1835 and 1850 (Telford 1926)) that hunting was curtailed sufficiently early to preserve remnants of the formerly extensive distribution of black squirrels in that area (Kennicott 1857).

An average of 40.7 percent of the remaining forests in this region are pastured, most heavily in Grundy, Kendall, Stark, and Woodford counties (Table 8).

Extensive areas in Will, Grundy, Bureau, La Salle, and Stark counties have been strip-mined for coal (Table 8). In the entire upper basin only 121 of

TABLE 4.—Continued.

Watershed	County	Township	Species	Stems per Ha	Basal Area (m²/ha)	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance Value Index (Percent)
Vermilion	Vermilion	McKendree[c] T18N, R11W, Section 14 (Upland)	Black oak	69	5.5	14.3	23.7	23.7	20.6
			Hickories (pignut, mockernut, bitternut)	47	1.8	12.2	16.1	7.8	12.1
			White oak	19	4.0	10.2	6.4	17.4	11.4
			Sugar maple	34	2.2	8.2	11.8	9.7	9.9
			Shagbark hickory	31	0.9	6.1	10.7	4.0	7.0
			American beech	16	1.9	6.1	5.4	8.4	6.6
			Northern red oak	12	1.3	6.1	4.3	5.5	5.3
			Tulip tree	12	1.2	6.1	4.3	5.1	5.2
			Ashes	9	0.9	6.1	3.2	4.0	4.4
			Sassafras	6	1.0	4.1	2.1	4.4	3.5
			Total	*255*	*20.7*	*79.5*	*88.0*	*90.0*	*86.0*
Iroquois	Iroquois	Concord[a] T27N, R11W, Section 30 (Upland)	Black oak	287	15.0	51.5	19.2	51.9	40.9
			White oak	79	5.1	14.3	17.3	17.8	16.5
			Northern red oak	48	3.3	8.7	13.5	11.4	11.2
			Black cherry	43	1.4	7.7	13.4	4.7	8.6
			Ashes	40	1.6	7.1	9.6	5.4	7.4
			Bitternut hickory	14	1.2	2.6	7.7	4.2	4.8
			Total	*511*	*27.6*	*91.9*	*80.7*	*95.4*	*89.4*
Iroquois	Iroquois	Douglas[a] T27N, R14W, Section 26 (Bottomland)	Ashes	156	10.8	29.1	25.0	29.4	27.8
			Elms	144	6.0	26.7	25.0	16.3	22.7
			Silver maple	113	8.4	20.9	15.0	22.9	19.6
			Basswood	69	2.9	12.8	5.0	8.0	8.6
			Hackberry	6	4.1	1.2	5.0	11.2	5.8
			Cottonwood	6	2.9	1.2	5.0	7.8	4.7
			Hawthorns	19	0.3	3.5	10.0	0.7	4.7
			Total	*513*	*35.4*	*95.4*	*90.0*	*96.3*	*93.9*

[a] Trees > 12.7 cm dbh. Trees tallied using 8- × 40-meter transects. (See Methods and Table 1 for sampling intensity.)

[b] Trees > 10.2 cm dbh. Data provided by R. & J. Graber, Illinois Natural History Survey. Trees tallied using 1/10-acre circular plots taken each 2 acres.

[c] Trees > 12.7 cm dbh. Plots 0.1 ha, taken each 60 meters.

[d] Trees > 10.2 cm dbh. Data from Crites & Ebinger (1969). Trees tallied using 25-m² plots in a complete census.

nearly 20,000 strip-mined acres have forests old enough to support squirrels (Table 8), and nearly all of those few acres are in Will County. Stream channelization has also been fairly extensive in the Upper Illinois River Region, particularly in Livingston, Will, Cook, La Salle, Kane, and Bureau counties (Table 8).

The Upper Illinois River Region currently contains over 7 million people, more than 50 percent of the human population of Illinois. Most of these people live in Cook County (Table 9), but human densities are now increasing more rapidly in the surrounding counties of Du Page, Kendall, Lake, and

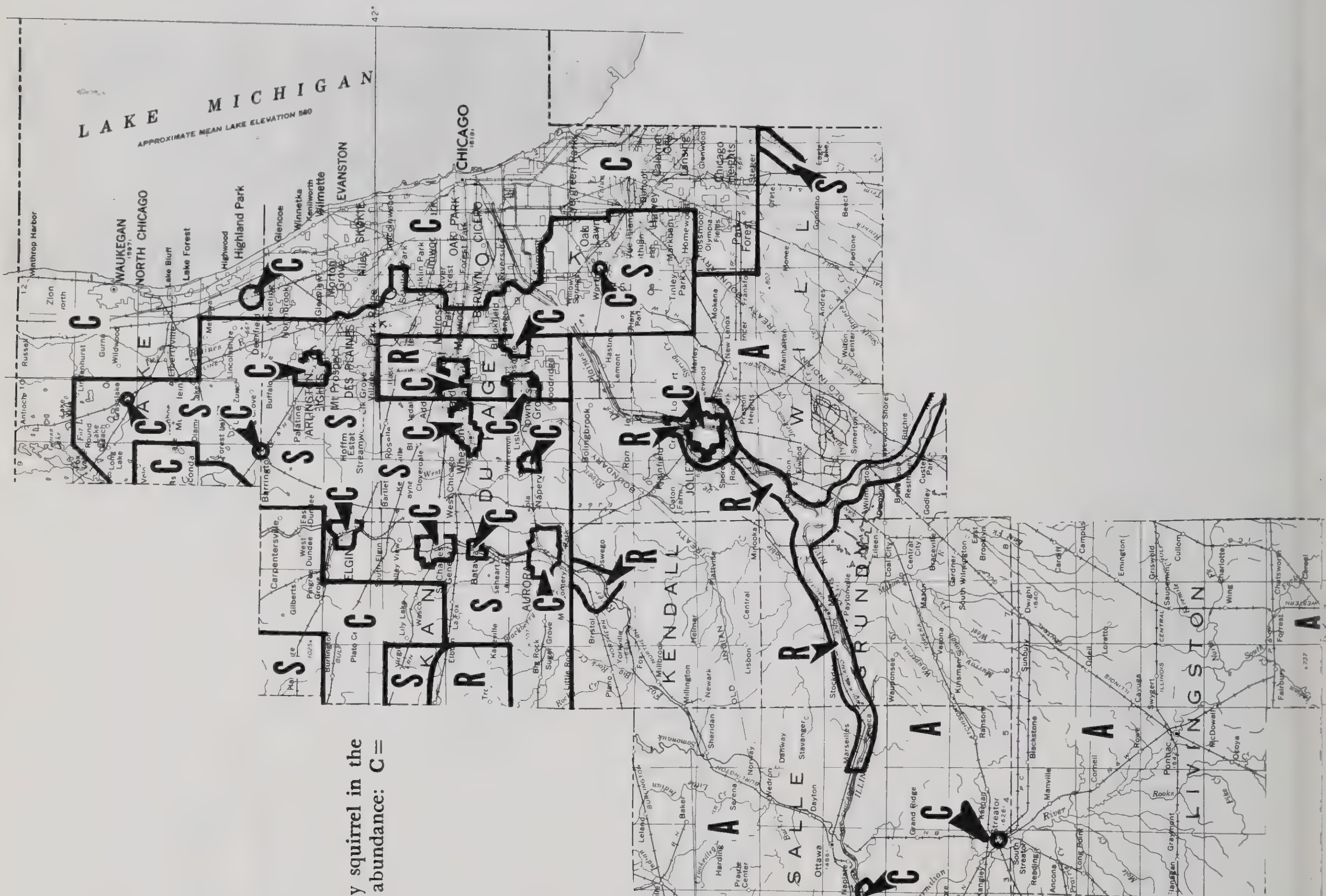


Fig. 6.—Distribution and relative abundance of the gray squirrel in the Upper Illinois River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

TABLE 5.—Estimated proportion of gray squirrels in the squirrel population of each watershed in 1800 compared with the percentage of gray squirrels in the squirrel harvests of 1956–1957. Estimates are based on the linear regression equation $Y = 4.48 + 1.48\ X$, where X = the estimated percentage of each watershed forested in 1800.

Watershed	Estimated Percent of Gray Squirrels in 1800 Squirrel Population	Average Percent of Gray Squirrels in 1956–1957 Squirrel Harvest	Change Between Sampling Periods (Percent)
Upper Mississippi	93.1	34.8	−62.6
Rock River	35.3	15.0	−57.5
Upper Illinois	28.2	12.0	−57.4
Lower Illinois	77.6	16.6	−78.6
Middle Mississippi	78.2	13.2	−83.1
Sangamon	24.2	3.6	−85.1
Kaskaskia	79.7	22.5	−71.8
Big Muddy	100.0	49.8	−50.2
Shawnee Hills	100.0	67.1	−32.9
Saline	100.0	56.6	−43.4
Little Wabash	92.5	28.6	−69.1
Embarras	73.7	20.9	−71.6
Vermilion	19.1	6.7	−64.9
Iroquois	13.5	0.9	−93.3

Will (Table 9). Gray squirrels will probably remain abundant in the urban parks and forest reserves of this region unless there is a drastic loss of forest cover. However, their future outside these forest reserves is uncertain.

Gray squirrels are most numerous on the state-owned conservation areas adjacent to the Illinois River in the southern portion of this region. These areas, located in Woodford and Marshall counties, should continue to provide quality hunting for gray squirrels.

The upland forests in the Upper Illinois River Region are among the poorest in Illinois in quality of timber. Because these woodlands contain little salable timber, there is little incentive for landowners to practice sustained timber management. Forests will persist in areas too rough for successful farming, but such areas are becoming very attractive for water impoundments and housing developments. The close proximity of Peoria to the occupied gray squirrel ranges in Woodford and Marshall counties probably means that these ranges will eventually be lost as more people move into these counties.

Lower Illinois River Region

The Lower Illinois River Region stretches from northern Peoria County to the junction of the Illinois River with the Mississippi. It includes tributaries of the La Moine, Mackinaw, and Spoon rivers and Kickapoo, Sugar, and Macoupin creeks (Fig. 7).

This region lies in a glacial valley forming a part of the former Mississippi seabed (Illinois State Planning Commission 1940). The streams and rivers flow through Illinoian drift, but surface deposit consists of a layer of Wisconsinan loess 5–20 feet thick. The topography is gently rolling and the Illinois River is paralleled by fairly high bluffs. Where the Mississippi and Illinois rivers converge, the terrain becomes rougher. In Calhoun County only a narrow ridge separates the valleys of the two rivers (Illinois State Planning Commission 1940). The portions of Calhoun County that were never glaciated exhibit the typical dissected upland topography noted in Jo Daviess and Carroll counties.

The upland forests in Schuyler County that we sampled showed a mixture of species, with species dominance dependent on site. Sugar maple, white oak, black oak, and hickories were the most important species (Table 4). As in Woodford County, however, these forests are generally understocked and poor in quality but contain species that provide adequate food and den sites for squirrels.

The Lower Illinois River Region averaged about 50 percent forested in 1800 and still contains more than 671,000 acres of forest (Table 3). Forests are scarce in the northern portion of the region in Tazewell, McDonough, Warren, and Knox counties, but counties in the lower portion of the basin remain extensively forested (Calhoun, 36.6 percent; Jersey, 23.2 percent) (Table 3).

In 1800 gray squirrels made up an estimated 77.6 percent of the squirrel population in the Lower Illinois River Region (Table 5). By 1956–1957 this proportion was reduced by 78.6 percent to an average of 16.6 percent of the squirrel harvest (Table 6). This decline is nearly identical to the 73.4 percent loss of forest land in the basin from 1800 to 1962 (Table 3).

Gray squirrels are now abundant in the counties of the lower portion of the basin. East and west of the Illinois River in the upper basin of the lower river they are scarce or absent (Fig. 7). Gray squirrels are scarce north of Bernadotte in Fulton County. In the 1880's Strode (1887) reported that both gray and fox squirrels were abundant along the Spoon River near Bernadotte. Gray squirrels made up 48.8 percent of a sample of 41 squirrels shot in 1973 on Sugar Creek in Schuyler County, where they are still common. Gray squirrels are generally scarce along most of the La Moine River (Fig. 7). They are common on the west side of the Illinois River in Peoria County but are scarce on the east side except in East Peoria (Tazewell County) (Fig. 7). Gray squirrels are absent from most of Knox and Warren counties, northern McDonough and eastern Scott counties, and are rare in most of Morgan County. They are common in the cities of Peoria (Peoria County), East Peoria (Tazewell County), and Jacksonville (Morgan County).

Gray squirrels comprise about 20 percent of the squirrel harvest from the Lower Illinois River Region (Table 6). They are most abundant in harvests from Calhoun, Jersey, Macoupin, Brown, Greene, and Schuyler counties (Table 6). They were significantly ($P < 0.01$) more abundant in the squirrel harvests of

TABLE 6.—Gray and fox squirrels reported shot by hunters in 1956–1957 and 1971–1973 in each major watershed in Illinois.

Watershed and County	Mail Questionnaire[a] 1956–1957				Mail Questionnaire[b] 1971–1973			
	Number Fox	Number Gray	Total	Percent Gray	Number Fox	Number Gray	Total	Percent Gray
Upper Mississippi								
Jo Daviess	310	204	514	40.0	195	131	326	40.2
Carroll	253	97	350	28.0	124	40	164	24.4
Total or mean	*563*	*301*	*864*	*34.8*	*319*	*171*	*490*	*34.9*
Rock River								
Boone	128	25	153	16.3	38	10	48	20.8
De Kalb	89	12	101	11.9	68	2	70	2.9
Henry	536	47	583	8.8	250	32	282	11.3
Lee	305	47	352	13.4	189	5	194	2.6
McHenry	403	113	516	21.9	86	130	216	60.2
Ogle	272	32	304	10.5	126	23	149	15.4
Stephenson	412	69	481	14.3	206	36	242	14.9
Whiteside	295	37	332	11.1	303	18	321	5.6
Winnebago	167	77	244	31.6	112	57	169	33.7
Total or mean	*2,607*	*459*	*3,066*	*15.0*	*1,378*	*313*	*1,691*	*18.5*[c]
Upper Illinois								
Bureau	425	42	467	9.0	433	79	512	15.4
Cook	276	71	347	20.5	61	9	70	12.9
Du Page	159	24	183	13.1	42	19	61	31.1
Grundy	243	22	265	8.3	160	25	185	13.5
Kane	200	32	232	13.8	151	21	172	12.2
Kendall	212	13	225	5.8	28	0	28	0.0
Livingston	159	5	164	3.0	127	2	129	1.6
Lake	302	88	390	12.6	82	197	279	70.6
La Salle	483	50	533	9.4	513	33	546	6.1
Marshall	420	70	490	14.3	340	119	459	25.9
Putnam	200	23	223	11.3	102	16	118	13.6
Stark	290	5	295	1.7	66	1	67	1.5
Will	224	8	232	3.4	180	51	231	22.1
Woodford	427	93	520	17.9	192	59	251	30.7
Total or mean	*4,020*	*546*	*4,566*	*12.0*	*2,477*	*631*	*3,108*	*20.3*[c]
Lower Illinois								
Brown	292	70	362	19.3	119	65	184	35.3
Calhoun	332	236	568	41.5	386	403	789	51.1
Cass	166	92	258	35.7	360	57	417	13.7
Fulton	1,000	186	1,186	15.7	572	47	619	7.6
Greene	699	141	840	16.8	413	154	567	27.2
Jersey	434	251	685	36.6	262	205	467	43.9
Knox	751	113	864	13.1	215	50	265	18.9
Macoupin	1,074	106	1,180	9.0	781	254	1,035	24.5
McDonough	579	23	602	3.8	184	18	202	8.9
Morgan	394	10	404	2.5	285	24	309	7.8
Peoria	1,141	224	1,365	16.4	373	71	444	16.0
Schuyler	295	109	404	17.0	149	47	196	24.0
Scott	271	46	317	14.5	216	12	228	5.3
Tazewell	818	56	874	6.4	378	30	408	7.4
Warren	342	44	386	11.4	24	1	25	4.0
Total or mean	*8,588*	*1,707*	*10,295*	*16.6*	*4,717*	*1,438*	*6,155*	*23.4*[c]
Middle Mississippi								
Adams	711	88	799	11.0	729	79	808	9.8
Hancock	584	9	593	1.5	227	9	236	3.8
Henderson	174	2	176	1.1	142	24	166	14.5
Mercer	263	50	313	16.0	224	89	313	28.4
Pike	757	198	955	20.7	439	257	696	36.9
Rock Island	609	124	733	16.9	349	165	514	32.1
Total or mean	*3,098*	*471*	*3,569*	*13.2*	*2,110*	*623*	*2,733*	*22.8*[c]
Sangamon								
Christian	483	47	530	8.9	310	15	325	4.6
De Witt	195	11	206	5.3	106	0	106	0.0
Logan	250	3	253	1.2	143	6	149	4.0
Macon	394	15	409	3.7	71	4	75	5.3
Mason	489	18	507	3.6	273	25	298	8.4
McLean	230	0	230	0.0	247	1	248	0.4
Menard	144	10	154	6.5	69	4	73	5.5
Piatt	362	2	364	0.6	110	3	113	2.7
Sangamon	535	9	544	1.7	222	16	238	6.7
Total or mean	*3,082*	*115*	*3,197*	*3.6*	*1,551*	*74*	*1,625*	*4.5*

TABLE 6.—Continued.

Watershed and County	Mail Questionnaire[a] 1956–1957				Mail Questionnaire[b] 1971–1973			
	Number Fox	Number Gray	Total	Percent Gray	Number Fox	Number Gray	Total	Percent Gray
Kaskaskia								
Bond	198	120	318	37.7	178	53	231	22.9
Clinton	190	118	308	38.3	148	254	402	63.2
Fayette	400	489	889	55.0	165	126	293	43.3
Madison	1,027	112	1,139	9.8	331	66	397	16.6
Marion	334	327	661	49.5	119	123	242	50.8
Monroe	429	308	737	41.8	96	104	200	52.0
Montgomery	773	218	991	22.0	161	100	261	38.3
Moultrie	215	48	263	18.3	60	21	81	25.9
Randolph	562	400	962	41.6	306	340	646	52.6
Shelby	565	236	801	29.5	95	88	183	48.1
St. Clair	599	101	700	14.4	159	106	265	40.0
Washington	510	322	832	38.7	60	100	160	37.5
Total or mean	*5,802*	*2,799*	*8,601*	*22.5*	*1,878*	*1,481*	*3,361*	*44.1*[c]
Big Muddy								
Franklin	287	309	596	51.8	257	328	585	56.1
Jackson	404	437	841	52.0	33	56	89	37.1
Jefferson	127	199	326	61.0	51	47	98	48.0
Perry	683	316	999	31.6	106	94	200	47.0
Williamson	352	574	926	62.0	86	154	240	64.2
Total or mean	*1,853*	*1,835*	*3,688*	*49.8*	*533*	*679*	*1,212*	*56.0*[c]
Shawnee Hills								
Alexander	325	244	569	42.9	48	105	153	68.6
Hardin	91	372	463	80.3	15	61	76	80.3
Johnson	192	450	642	70.1	94	221	315	70.2
Massac	101	395	496	79.6	53	87	140	62.1
Pope	87	359	446	81.5	34	109	143	76.2
Pulaski	208	135	343	39.4	36	73	109	67.0
Union	226	552	778	71.0	50	104	154	67.4
Total or mean	*1,230*	*2,507*	*3,737*	*67.1*	*330*	*760*	*1,090*	*69.7*
Saline								
Gallatin	215	233	448	52.0	67	46	113	40.7
Hamilton	156	348	504	69.0	148	173	321	53.9
Saline	226	199	425	46.8	62	46	108	42.6
Total or mean	*597*	*780*	*1,377*	*56.6*	*277*	*265*	*542*	*48.9*[c]
Little Wabash								
Clay	403	129	532	24.2	311	266	577	46.1
Edwards	92	20	112	17.9	36	36	72	50.0
Effingham	372	176	548	32.1	72	36	108	33.3
Richland	477	286	763	37.5	105	110	215	51.2
Wabash	176	18	194	9.3	20	10	30	33.3
Wayne	357	174	531	32.8	168	98	266	36.8
White	426	118	544	21.7	12	11	23	47.8
Total or mean	*2,303*	*921*	*3,224*	*28.6*	*724*	*567*	*1,291*	*43.9*[c]
Embarras								
Clark	540	194	734	26.4	268	63	331	19.0
Coles	475	152	627	24.2	182	40	222	18.0
Crawford	341	140	481	29.1	114	27	141	19.1
Cumberland	112	71	183	38.8	98	53	151	35.1
Douglas	244	6	250	2.4	100	2	102	2.0
Edgar	389	12	401	3.0	226	43	269	16.0
Jasper	283	88	371	23.7	85	33	118	28.0
Lawrence	357	63	420	15.0	49	24	73	32.9
Total or mean	*2,741*	*726*	*3,467*	*20.9*	*1,122*	*285*	*1,407*	*20.3*
Vermilion								
Champaign	112	9	121	7.4	56	5	61	8.1
Ford	105	10	115	8.7	45	0	45	0.0
Vermilion	635	42	677	6.2	271	20	291	6.9
Total or mean	*852*	*61*	*913*	*6.7*	*372*	*25*	*397*	*6.3*
Iroquois								
Iroquois	280	0	280	0.0	214	2	216	0.9
Kankakee	157	4	161	2.5	138	20	158	12.7
Total or mean	*437*	*4*	*441*	*0.9*	*352*	*22*	*374*	*5.9*

[a] Total sample = 50,852 squirrels (W. L. Preno, Illinois Department of Conservation, personal communication, 1973).
[b] Total sample = 30,886 squirrels (W. L. Preno, Illinois Department of Conservation, personal communication, 1971–1973).
[c] Significantly different ($P < 0.01$) from the total percentage for gray squirrels in the watershed squirrel harvests of 1956–1957.

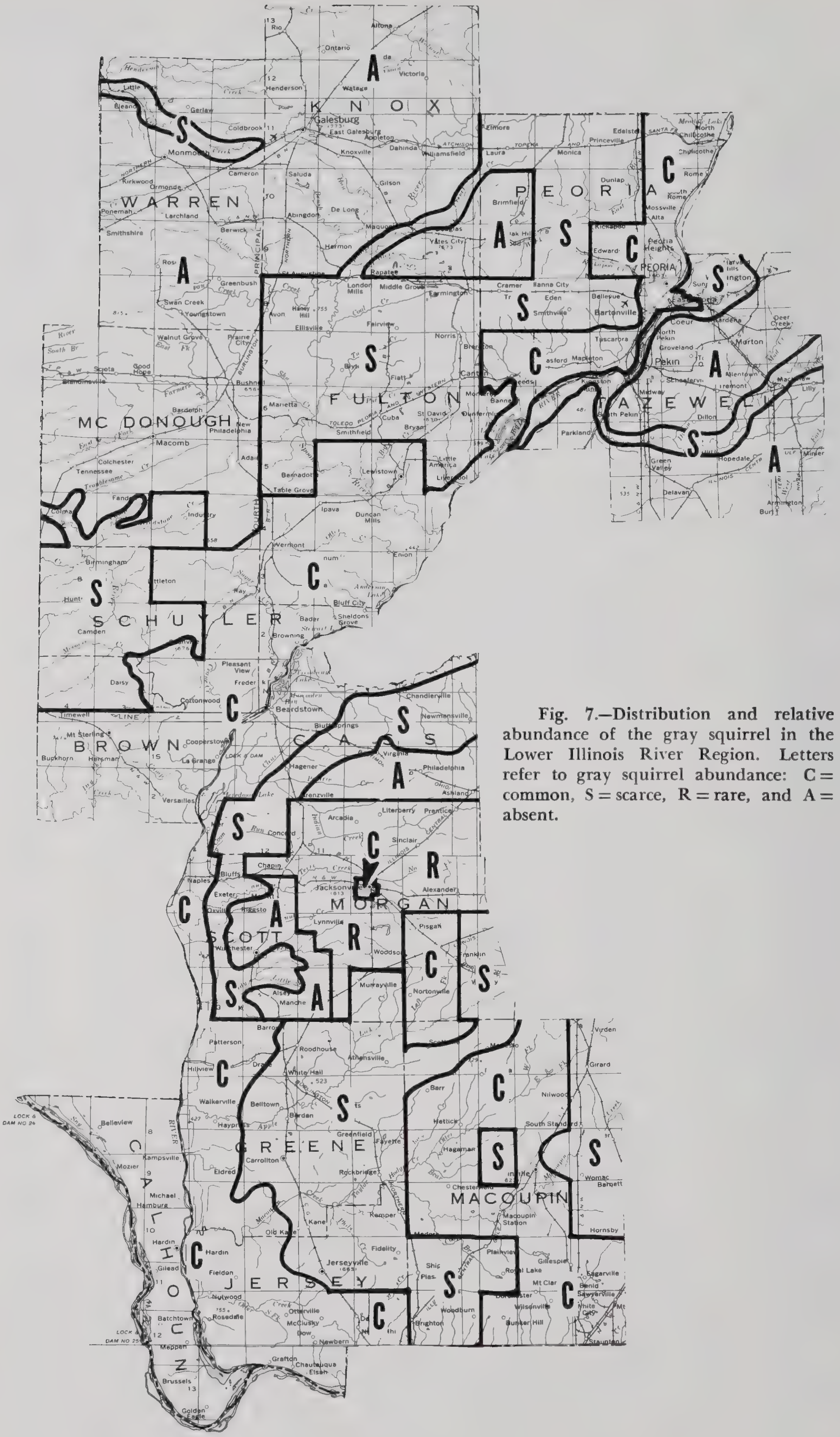


Fig. 7.—Distribution and relative abundance of the gray squirrel in the Lower Illinois River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

TABLE 7.—Locations of melanistic populations of gray squirrels in Illinois.

Watershed	County	Location
Upper Mississippi	Jo Daviess	City of East Dubuque City of Hanover
	Carroll	City of Mt. Carroll (scarce)
Upper Illinois	Cook	Village of Winnetka
	Lake	City of Highland Park
	Cook	Village of Glencoe
	Cook	Village of Northbrook
	Lake	USVA Hospital, City of North Chicago
	Lake	City of Zion
	Lake	City of Lake Forest
	Cook	Village of Wilmette (scarce)
	Cook	City of Evanston (scarce)
	Lake	Fort Sheridan
Middle Mississippi	Rock Island	City of Rock Island
	Rock Island	City of Moline
	Rock Island	U.S. Army, Rock Island Arsenal
	Rock Island	Black Hawk State Park
	Adams	City of Quincy (very rare)
All other watersheds	None	None

1971–1973 in this region than in the harvests of 1956–1957 (Table 6). Proportionate harvests of gray squirrels increased in Brown, Calhoun, Greene, Jersey, Macoupin, Schuyler, and Knox counties in 1971–1973 (Table 6). Forest cover decreased in most of these counties between 1948 and 1962 (Table 3). We reiterate that the increases in the proportionate harvests of gray squirrels are the result of woodlot removal, forcing hunters into forests occupied by both species.

Comparing the present distribution of gray squirrels with the distribution in 1942 (Fig. 3) indicates that their abundance has not changed appreciably in the basin since 1942. Although gray squirrels may appear to be more widespread in Macoupin, Greene, Peoria, and Fulton counties today (Fig. 3 and 7), this apparent prevalence may only reflect an insufficient survey of occupied range in 1942.

Gray squirrels were considered common in McDonough County at the turn of the century, and an occasional black squirrel (presumably gray) was seen (Bateman et al. 1907). Today they have apparently been extirpated from all but the southernmost townships (Fig. 7).

At present about 44 percent of the forests in the entire basin are pastured; over half the forests in Calhoun, Cass, Fulton, Knox, McDonough, Schuyler, and Scott counties are used as pasture (Table 8).

It is fortunate that many streams in the basin remain unchannelized (Table 8). The main problem continues to be the building of levees and the clearing of floodplain forests along the Illinois River. Once levees are in place, the conversion of forest lands to croplands is usually rapid (Mills et al. 1966). Initially (prior to 1900), 400,000 acres of bottomland were subject to river flooding between La Salle and Grafton (Mills et al. 1966). At the height of drainage activity (1920's), there were 38 drainage districts and three private drainage areas aggregating 200,000 acres, or half the available flooded bottomlands (Mills et al. 1966). Since then, some drainage districts have failed, and nearly 8,000 acres (4.0 percent) have been returned to forests, sloughs, and marshes (Mills et al. 1966).

More than 66,000 acres of the lower Illinois basin have been strip-mined for coal, nearly 41,000 acres in Fulton County (Table 8). At least some of this strip-mined land was prairie, not forest, but as only 261 of these acres have succeeded to maturing forests since they were strip-mined, forest wildlife in the basin has suffered substantial losses of habitat.

Human densities increased about 5 percent in this region between 1960 and 1970, with only Tazewell and McDonough counties showing substantial growth (Table 9). The human population decreased in several counties in the lower basin during the 1960's (Table 9).

Gray squirrels appear to be reasonably secure in the Lower Illinois River Region if the remaining forests are not drastically altered by overcutting or completely destroyed. Land purchase by Illinois in the Lake Meredosia area in Morgan and Cass counties would provide a substantial refuge for wildlife in the lower Illinois basin. This purchase has been recommended by the Illinois Division of Waterways (1969).

The upland forests of the basin also contain gray squirrels. Thus, the continued loss of bottomland forest will not in itself eliminate gray squirrels from the region, at least not from the extensive forests of Calhoun and Jersey counties. In the upper counties, however, an expanding human population around the cities of Peoria and Macomb threatens to reduce forests adjacent to these areas. North of Liverpool in Fulton County, gray squirrels are abundant only along the Illinois River (Fig. 7), and any substantial alteration of bottomland forests in that area will reduce gray squirrel abundance.

Middle Mississippi River Region

The six-county area we chose to call the Middle Mississippi River Region (Fig. 8) was glaciated during the Pleistocene. Deep, well-drained loess soils cover most of the uplands. The bottomland soils are sandy where they were frequently inundated but contain more clay along the bluffs (Telford 1926). Three distinct topographic areas occur in the region: (1) a flat to undulating upland plain dissected by numerous small streams; (2) a bluff region of rugged hills broken by many valleys tending east and west; and (3) the floodplain of the Mississippi River, which varies from

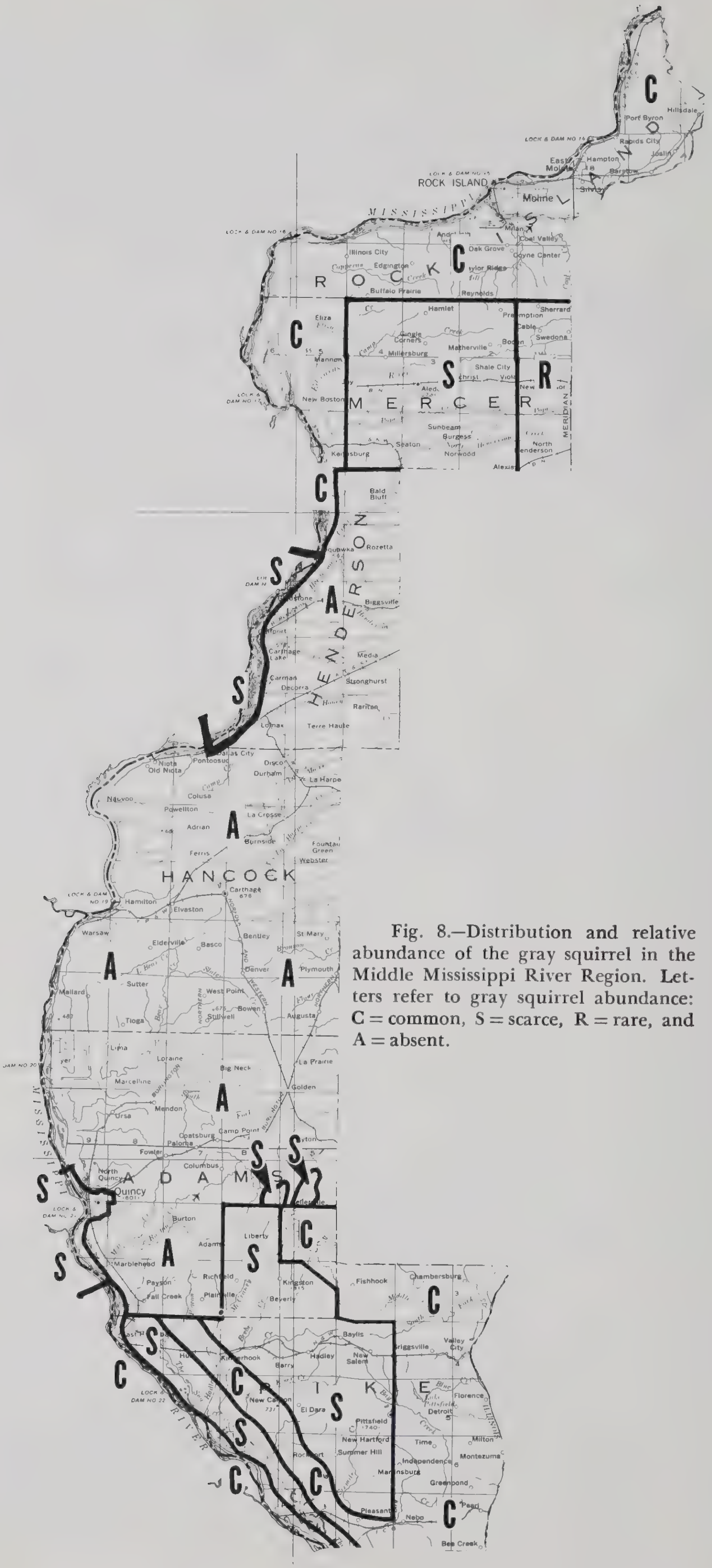


Fig. 8.—Distribution and relative abundance of the gray squirrel in the Middle Mississippi River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

large tracts of farmlands to swamps and abrupt sand terraces (Telford 1926).

The region was about 50 percent forested in 1800 but is only about 11 percent forested today (Table 3). Most of the bottomland forests have been removed and those that remain bear little resemblance to those of presettlement times (Telford 1926). A bottomland forest adjacent to the Mississippi River in Henderson County was dominated by silver maple, ashes, pin oak, and cottonwood (Table 4). This stand seems similar to one also adjacent to the Mississippi River in Union County that Telford (1926: 6) measured in the 1920's. The upland forests, similar to those measured in Schuyler County (Table 4), have been generally overcut and frequently burned, and are usually pastured.

Gray squirrels comprised an estimated 78.2 percent of the squirrel population in this region in 1800 (Table 5) but make up only about 20 percent of the squirrel harvest there today (Table 6). Gray squirrels are abundant in Rock Island County, western Mercer County, the northwestern corner of Henderson County, southeastern Adams County along McKee Creek, and much of Pike County. They are absent from all of Hancock County and most of Adams and Henderson counties (Fig. 8). We feel that the gray squirrels recorded by hunters in 1956–1957 and 1971–1973 in Hancock County (Table 6) represent hunter error in calling fox squirrels gray squirrels, because we can find no verified reports of their presence in the county. They are found in Quincy, Adams County, and are common in the Quad Cities area (Rock Island County), particularly in Moline and Rock Island.

The absence of gray squirrels along the Mississippi River in Hancock and Adams counties can be explained by the extensive clearing of the bottomland forests that has occurred since settlement (Telford 1926). The absence of gray squirrels from the upland forests in the basin, particularly in Adams County, is not so easily explained. In 1962 Adams County contained nearly 70,000 acres of forest (Table 3), more forest than was found in Rock Island County in 1962, where gray squirrels are still abundant. About 64 percent of the forests in Adams County are pastured (Table 8), but so are about 66 percent of the forests in Mercer County. Yet gray squirrels are abundant along McKee Creek in southeastern Adams County. Gray squirrels constituted 86.9 percent of 481 squirrels shot by hunters in 1972–1973 at Siloam Springs State Park located on McKee Creek on the Adams-Brown county line. McKee Creek drains into the lower Illinois River, and we believe the gray squirrels on McKee Creek belong to the extensively occupied range in the lower Illinois basin (Brown County, Fig. 7). It seems unlikely that the gray squirrels along McKee Creek ranged west across Adams County to the Mississippi River. Prairie vegetation dominated the townships north and west of McKee Creek when the area was first surveyed in the 1830's (J. White, Illinois Natural Areas Inventory, personal communication, 1975).

Brown & Yeager (1945) showed gray squirrels present all through western Henderson and Adams counties (Fig. 3) but did not report them as present in southeast Adams County along McKee Creek, where they are abundant today (Fig. 3 and 8). Mohr (1941) also reported gray squirrels to be abundant south of Oquawka in Henderson County, where they are now scarce (Fig. 8).

In the six-county region, melanistic gray squirrels are found regularly only in the cities of Moline and Rock Island, in the area of the Rock Island Arsenal, and in Black Hawk State Park, Rock Island County (Table 7).

Within the basin, gray squirrels are most secure in the upland forests of Pike County. Gray squirrel range in Rock Island and Mercer counties is less secure because of the increasing human population in the Quad Cities area. Any permanent rise of the Mississippi River will necessitate new levees, resulting in losses of bottomland forests. If water levels rise, bottomland forests not protected by levees, as in Big River State Forest, Henderson County, would be doomed. Because most of the forests in the Middle Mississippi River Region are not secure, we expect the gray squirrel to continue to decline in abundance in this region.

Sangamon River Region

The Sangamon River (Fig. 9) begins in and flows to its juncture with the Illinois River across what was once known as the "Grand Prairie." This region, nearly all covered with prairie grasses in 1800, consists of a level, poorly drained plain of relatively young glacial drift (Jones & Bell 1974). Moraines and other glacial landforms are common. Soils are young and high in organic matter, having developed under prairie grasses from loess or from glacial drift. Soils of the lower basin (Mason County) are derived from sand deposited by the outwash from the Wisconsinan glacier. In the upper part of the region, the upland forests have been heavily disturbed and are generally dominated by elms, hackberry, bur oak, and honey locust (Table 4). Bottomland forests of the region have also been extensively cut and are often nearly a monotype of silver maple (Table 4). The percentage of oak in the upland forests has declined since settlement (Mohlenbrock 1975) because of the selective cutting of oaks and extensive pasturing.

Forests in Mason County adjacent to the Illinois River, where gray squirrels are still common, are dominated by silver maple although it is less important in the bottomlands of Mason County than it is in most of the forests of the region (Table 4). Cottonwood, pin oak, elms, box elder, ashes, and pecan are also important components of the tree stratum in

TABLE 8.—Land-use practices potentially destructive to gray squirrel habitat and the number of strip-mined acres covered with maturing forest in 1971.

Watershed and County	Percent of County Forest Area Pastured[a]	Miles of Streams Channelized[b]	Acres Strip-mined for Coal[c]	Strip-mined Acres Covered with Maturing Forest[e]
Upper Mississippi				
Jo Daviess	65.1	5.6	None	. . .
Carroll	46.9	18.8	None	. . .
Total	*112.0*	*24.4*	*0.0*	. . .
Mean	*56.0*	*12.2*		
Rock River				
Boone	75.8	25.3	None	. . .
De Kalb	26.3	194.0	None	. . .
Henry	71.7	280.6	2,676.0	81.0
Lee	30.0	119.1	None	. . .
McHenry	30.3	257.6	None	. . .
Ogle	49.8	37.2	None	. . .
Stephenson	65.5	No data	None	. . .
Whiteside	54.7	277.0	None	. . .
Winnebago	74.2	15.6	None	. . .
Total	*478.3*	*1,206.4*	*2,676.0*	*81.0*
Mean	*53.1*	*150.8*		
Upper Illinois				
Bureau	47.5	149.9	3,135.0	16.0
Cook	9.8	184.3	None	. . .
Du Page	None[d]	28.4	None	. . .
Grundy	62.7	27.3	7,134.0	5.0
Kane	16.2	152.0	None	. . .
Kendall	66.7	36.9	None	. . .
Livingston	17.3	246.7	46.0	0.0
Lake	20.1	45.1	None	. . .
La Salle	51.6	155.7	1,213.0	0.0
Marshall	43.0	11.1	1.0	0.0
Putnam	50.0	10.0	None	. . .
Stark	60.1	29.0	1,992.0	0.0
Will	24.9	190.2	6,067.0	100.0
Woodford	60.4	35.4	None	. . .
Total	*530.3*	*1,302.0*	*19,588.0*	*121.0*
Mean	*40.8*	*93.0*		
Lower Illinois				
Brown	41.4	18.0	19.0	0.0
Calhoun	51.5	18.5	None	. . .
Cass	68.4	71.0	None	. . .
Fulton	57.8	116.9	40,524.0	229.0
Greene	32.1	102.8	56.0	0.0
Jersey	26.8	16.9	1.0	0.0
Knox	73.0	7.5	17,350.0	32.0
Macoupin	35.0	26.1	None	. . .
McDonough	57.3	1.0	None	. . .
Morgan	5.8	24.5	4.0	0.0
Peoria	24.4	18.1	6,187.0	0.0
Schuyler	57.9	45.6	2,064.0	0.0
Scott	75.9	43.5	1.0	0.0
Tazewell	37.2	60.5	None	. . .
Warren	17.4	13.1	None	. . .
Total	*661.9*	*584.0*	*66,206.0*	*261.0*
Mean	*44.1*	*38.9*		
Middle Mississippi				
Adams	64.1	74.0	228.0	18.0
Hancock	53.3	38.2	101.0	0.0
Henderson	45.9	77.1	None	. . .
Mercer	65.8	54.3	25.0	0.0
Pike	46.7	137.9	1.0	0.0
Rock Island	54.2	83.1	None	. . .
Total	*330.0*	*464.6*	*355.0*	*18.0*
Mean	*55.0*	*77.4*		
Sangamon				
Christian	18.2	87.0	None	. . .
De Witt	50.0	25.0	None	. . .
Logan	2.3	138.5	None	. . .
Macon	33.9	76.0	None	. . .
Mason	42.0	210.5	None	. . .
McLean	26.7	133.1	None	. . .
Menard	33.4	34.5	6.0	0.0
Piatt	14.3	124.6	None	. . .
Sangamon	50.1	2.0	None	. . .
Total	*270.9*	*831.2*	*6.0*	*0.0*
Mean	*30.1*	*92.4*		
Kaskaskia				
Bond	47.6	12.2	None	. . .
Clinton	16.5	25.1	None	. . .
Fayette	50.0	34.5	None	. . .
Madison	16.1	48.9	7.0	0.0
Marion	26.0	1.0	None	. . .
Monroe	5.8	78.7	None	. . .
Montgomery	55.6	160.3	None	. . .
Moultrie	47.1	44.8	None	. . .
Randolph	26.8	14.2	5,425.0	146.0
Shelby	25.0	33.0	None	. . .
St. Clair	9.2	63.1	12,482.0	342.0
Washington	13.9	No data	None	. . .
Total	*339.6*	*515.8*	*17,914.0*	*488.0*
Mean	*28.3*	*43.0*		
Big Muddy				
Franklin	No data	9.3	None	. . .
Jackson	40.6	59.8	4,899.0	40.0
Jefferson	6.8	5.0	387.0	0.0
Perry	11.6	No data	20,317.0	970.0
Williamson	11.5	33.5	12,701.0	823.0
Total	*70.5*	*107.6*	*38,304.0*	*1,833.0*
Mean	*17.6*	*21.5*		
Shawnee Hills				
Alexander	None	42.8	None	. . .
Hardin	7.5	None	None	. . .
Johnson	42.3	25.8	50.0	0.0
Massac	12.1	71.7	None	. . .
Pope	10.8	26.5	26.0	0.0
Pulaski	9.6	118.5	None	. . .
Union	10.6	61.7	None	. . .
Total	*92.9*	*347.0*	*76.0*	*0.0*
Mean	*13.3*	*49.6*		
Saline				
Gallatin	14.3	166.3	1,483.0	0.0
Hamilton	5.8	119.8	None	. . .
Saline	10.8	182.0	9,504.0	0.0
Total	*30.9*	*468.1*	*10,987.0*	*0.0*
Mean	*10.3*	*156.0*		
Little Wabash				
Clay	18.5	11.0	None	. . .
Edwards	18.5	22.5	None	. . .

TABLE 8.—Continued.

Watershed and County	Percent of County Forest Area Pastured[a]	Miles of Streams Channelized[b]	Acres Strip-mined for Coal[c]	Strip-mined Acres Covered with Maturing Forest[c]
Effingham	25.0	6.3	None	. . .
Richland	34.2	7.0	None	. . .
Wabash	21.1	31.5	10.0	0.0
Wayne	18.3	66.0	None	. . .
White	31.5	59.0	None	. . .
Total	*167.1*	*203.3*	*10.0*	*0.0*
Mean	*23.9*	*29.0*		
Embarras				
Clark	57.8	21.6	3.0	0.0
Coles	33.8	70.3	None	. . .
Crawford	9.7	33.0	4.0	0.0
Cumberland	37.2	16.1	None	. . .
Douglas	42.6	112.7	None	. . .
Edgar	45.3	148.0	51.0	0.0
Jasper	52.9	16.0	None	. . .
Lawrence	51.5	90.5	None	. . .
Total	*330.8*	*508.2*	*58.0*	*0.0*
Mean	*41.4*	*63.5*		
Vermilion				
Champaign	28.2	390.3	None	. . .
Ford	53.5	351.8	None	. . .
Vermilion	50.0	114.6	5,297.0	31.0
Total	*131.7*	*856.7*	*5,297.0*	*31.0*
Mean	*43.9*	*285.6*		
Iroquois				
Iroquois	29.8	470.3	None	. . .
Kankakee	7.9	340.7	2,160.0	0.0
Total	*37.7*	*811.0*	*2,160.0*	*0.0*
Mean	*18.9*	*405.5*		

[a] Illinois Conservation Needs Committee (1970). [b] Lopinot (1972). [c] Haynes & Klimstra (1975). [d] Obvious error.

these bottomlands and provide squirrels with an extensive food base (Table 4). The upland forests in Mason County grow on sandy soils and generally have fewer species. One upland stand in Mason County contained only black and blackjack oaks (Table 4).

The Sangamon basin averaged only 13.3 percent forest in 1800. The earliest survey of the region shows that only in Menard County were extensive forests found away from the river. The region averages only 3.6 percent forest today, but Mason County actually contains more forest now than it had in 1800 (Table 3). The sandy soils of Mason County are generally droughty and unsuited to grain culture and have been extensively planted to pines to stabilize the sand dunes. These pine stands are not occupied by gray squirrels.

Except in various urban parks, gray squirrels are common only in the Sangamon-Illinois river bottomlands, in adjacent uplands in Mason County, and in the forests southeast of Pana in Christian County (Fig. 9). Gray squirrels are common in Springfield (Sangamon County) and Taylorville (Christian County). Mixed populations of gray and fox squirrels occur in Lincoln (Logan County), Bloomington (McLean County), and Decatur (Macon County), but fox squirrels are the more abundant.

A comparison of the present distribution with that of 1942 (Fig. 3) indicates that the gray squirrel has recently been extirpated from most of the Sangamon River bottomlands between Decatur and the Mason County line. As noted earlier, extensive cutting has left only small, nearly monotypic tracts of silver maple along most of the upper river.

Both Mohr (1941) and Brown & Yeager (1945) reported gray squirrels present in McLean County adjacent to Tazewell County (Fig. 3). Today, gray squirrels are present but scarce along portions of Funks Branch and Rock Creek in western McLean County and have been extirpated from the rest of the county. The surveys of 1941 and 1945 both reported the presence of gray squirrels in eastern Mason County, where there are none today.

As late as 1928–1929 nearly equal numbers of gray and fox squirrels occurred along the Sangamon south of White Heath, Piatt County (Goff 1952), but they were apparently extirpated shortly thereafter (D. R. Vance, Illinois Natural History Survey, personal communication, 1974). A successful reintroduction of gray squirrels was made in the early 1970's in Monticello and also southeast of White Heath in the bottomlands along the Sangamon River. The reintroduction was a private project using stock obtained in Champaign-Urbana (D. R. Vance, personal communication, 1975). It seems likely that gray squirrels will soon invade Allerton Park, a 1,500-acre forested sanctuary located just south of Monticello. In 1918 an unsuccessful reintroduction was attempted 2 miles south of Athens in Menard County (Watson Hall, personal communication to Carl Mohr, Illinois Natural History Survey, 1944).

Gray squirrels constituted an estimated 24.2 percent of the presettlement squirrel population in the Sangamon River Region (Table 5) but constitute only about 4 percent of the squirrels harvested today (Table 6). We suspect that some of the gray squirrels reported shot in Champaign, De Witt, and Piatt counties are improperly identified although gray squirrels dispersing from the urban parks would be available to squirrel hunters in these counties.

The streams and rivers of the Sangamon basin have been extensively channelized (Table 8). The riparian forests associated with these streams are removed before maturity because drainage ditches are cleaned periodically of all tree cover. Only the forests in De Witt, Sangamon, and Mason counties are extensively pastured (Table 8).

Human densities are increasing in the basin, particularly in McLean and Sangamon counties (Table 9), and additional intrusions by humans into the remaining forests will further reduce the distribution

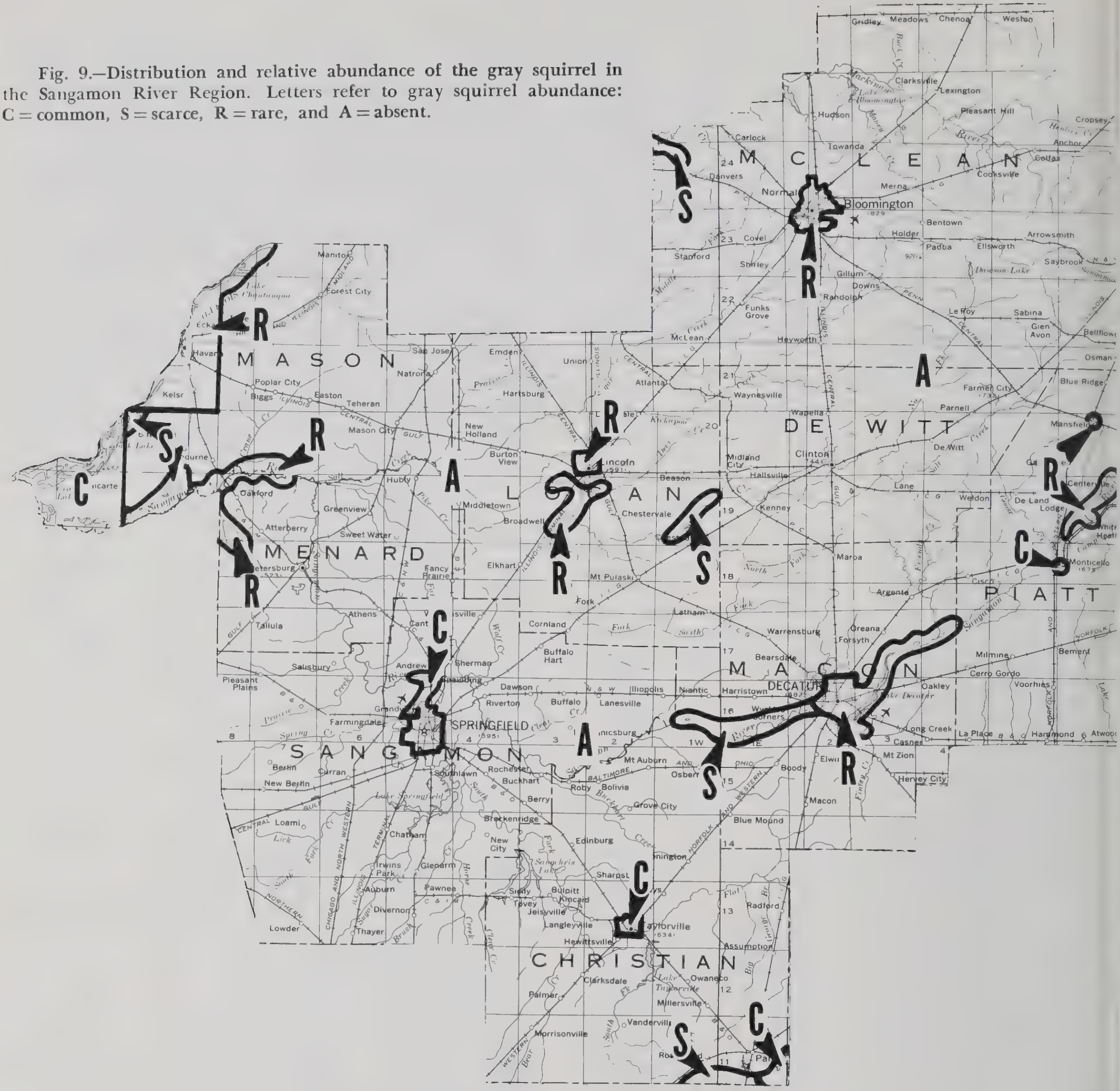


Fig. 9.—Distribution and relative abundance of the gray squirrel in the Sangamon River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

of the gray squirrel. We expect that the gray squirrel populations now listed as scarce or rare north and south of Decatur in Macon County, south and east of Lincoln in Logan County, and north of Petersburg in Menard County will be eliminated unless they find sanctuary in public parks and reserves. Populations of gray squirrels in urban areas in the basin should continue to flourish and even expand somewhat as trees planted in housing developments mature and begin to produce food and den sites. The best gray squirrel range in Mason County is the 8,000-acre Sanganois Conservation Area, a near wilderness of sloughs, forests, and swamps. The purchase of more forests, marshes, and sloughs surrounding this publi area, as recommended by the Illinois Division o Waterways (1969), would give additional protectio to the resident population of gray squirrels.

Kaskaskia River Region

The Kaskaskia River (Fig. 10) begins in a leve dissected plain and flows southwestward through rolling hills. The river is a low-gradient stream with fairly wide floodplain. Soils are predominantly loes developed under a nearly equal mixture of prairi and forest.

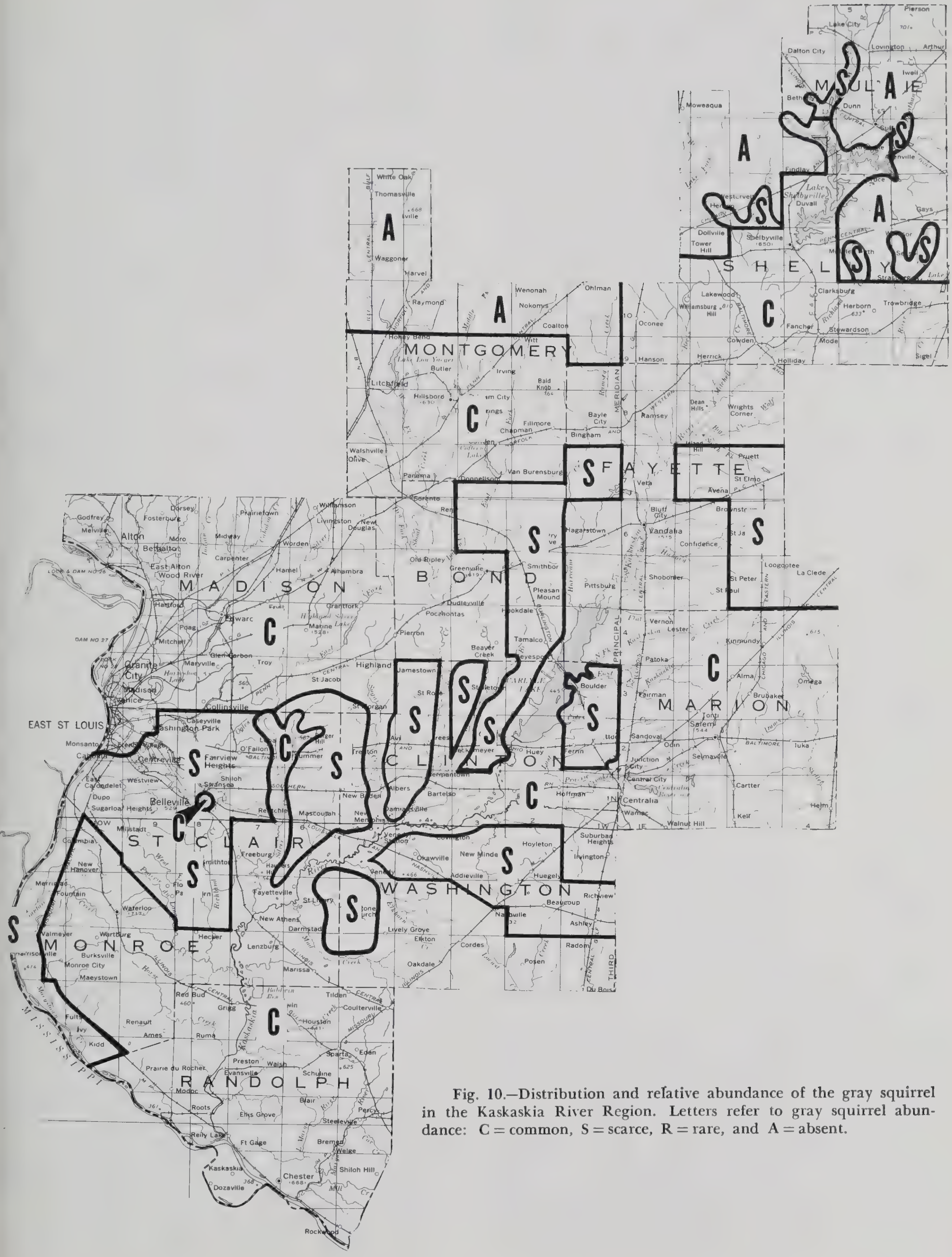


Fig. 10.—Distribution and relative abundance of the gray squirrel in the Kaskaskia River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

Table 9.—Human densities in each major watershed in Illinois, 1950–1970.

Watershed and County	1950[a]	1960[b]	1970[c]	Percentage of Change, 1960–1970
Upper Mississippi				
Jo Daviess	21,459	21,821	21,766	– 0.003
Carroll	18,976	19,507	19,276	– 0.012
Total or mean	*40,435*	*41,328*	*41,042*	*– 0.007*
Rock River				
Boone	17,070	20,326	25,440	+25.2
De Kalb	40,781	51,714	71,654	+38.6
Henry	46,492	49,317	53,217	+ 7.9
Lee	36,451	38,749	37,947	– 2.1
McHenry	50,656	84,210	111,555	+32.5
Ogle	33,429	38,106	42,867	+12.5
Stephenson	41,595	46,207	48,861	+ 5.7
Whiteside	49,336	59,887	62,877	+ 5.0
Winnebago	152,385	209,765	246,623	+17.6
Total or mean	*468,195*	*598,281*	*701,041*	*+17.2*
Upper Illinois				
Bureau	37,711	37,594	38,541	+ 2.5
Cook	4,508,792	5,129,725	5,492,369	+ 7.1
Du Page	154,599	313,459	491,882	+56.9
Grundy	19,217	22,350	26,535	+18.7
Kane	150,388	208,246	251,005	+20.5
Kendall	12,115	17,540	26,374	+50.4
Livingston	37,809	40,341	40,690	+ 0.008
Lake	179,097	293,656	382,638	+30.3
La Salle	100,610	110,800	111,409	+ 0.005
Marshall	13,025	13,334	13,302	– 0.002
Putnam	4,746	4,570	5,007	+ 9.6
Stark	8,721	8,152	7,510	– 7.9
Will	134,336	191,617	249,498	+30.2
Woodford	21,335	24,579	28,012	+13.9
Total or mean	*5,382,501*	*6,415,963*	*7,164,772*	*+11.7*
Lower Illinois				
Brown	7,132	6,210	5,586	–10.0
Calhoun	6,898	5,933	5,675	– 4.3
Cass	15,097	14,539	14,219	– 2.2
Fulton	43,716	41,954	41,890	. . .
Greene	18,852	17,460	17,014	– 2.6
Jersey	15,264	17,023	18,492	+ 8.6
Knox	54,366	61,280	61,280	. . .
Macoupin	44,210	43,524	44,557	+ 2.4
McDonough	28,199	28,928	36,653	+26.7
Morgan	35,568	36,571	36,174	– 1.1
Peoria	174,347	189,044	195,318	+ 3.3
Schuyler	9,613	8,746	8,135	– 6.9
Scott	7,243	6,377	6,096	– 4.4
Tazewell	76,165	99,789	118,649	+18.9
Warren	21,981	21,587	21,595	. . .
Total or mean	*558,651*	*598,965*	*631,333*	*+ 5.1*
Middle Mississippi				
Adams	64,690	68,467	70,861	+ 3.5
Hancock	25,790	24,574	23,645	– 3.8
Henderson	8,416	8,237	8,451	+ 2.6
Mercer	17,374	17,149	17,298	. . .
Pike	22,155	20,552	19,185	– 6.7
Rock Island	133,558	150,991	166,734	+10.4
Total or mean	*271,983*	*289,970*	*306,174*	*+ 5.6*
Sangamon				
Christian	38,816	37,207	35,948	– 3.4
De Witt	16,894	17,253	16,975	– 1.6
Logan	30,671	33,656	33,538	– 0.03
Macon	98,853	118,257	125,010	+ 5.7
Mason	15,326	15,193	16,161	+ 6.4
McLean	76,577	83,877	104,389	+24.5
Menard	9,639	9,248	9,685	+ 4.7
Piatt	13,970	14,960	15,509	+ 3.7
Sangamon	131,484	146,539	161,335	+10.1
Total or mean	*432,230*	*476,190*	*518,550*	*+ 8.9*
Kaskaskia				
Bond	14,157	14,060	14,042	– 0.001
Clinton	22,594	24,029	28,315	+17.8
Fayette	24,582	21,946	20,752	– 5.4
Madison	182,207	224,689	250,934	+11.7
Marion	41,700	39,349	38,986	– 0.009
Monroe	13,282	15,507	18,831	+21.4
Montgomery	32,460	31,244	30,260	– 3.1
Moultrie	13,171	13,635	13,263	– 2.7
Randolph	31,673	29,988	31,379	+ 4.6
Shelby	24,434	23,404	22,589	– 3.5
St. Clair	205,995	262,509	285,176	+ 8.6
Washington	14,460	13,569	13,780	+ 1.6
Total or mean	*620,715*	*713,929*	*768,307*	*+ 7.6*
Big Muddy				
Franklin	48,685	39,281	38,329	–21.3
Jackson	38,124	42,151	55,008	+30.5
Jefferson	35,892	32,135	31,446	– 2.1
Perry	21,684	19,184	19,757	+ 2.9
Williamson	48,621	46,117	49,021	+ 6.3
Total or mean	*193,006*	*178,868*	*193,561*	*+ 8.2*
Shawnee Hills				
Alexander	20,316	16,061	12,015	–25.2
Hardin	7,530	5,879	4,914	–16.4
Johnson	8,729	6,928	7,550	+ 9.0
Massac	13,594	14,341	13,889	– 3.2
Pope	5,779	4,061	3,857	– 5.0
Pulaski	13,639	10,490	8,741	–16.7
Union	20,500	17,645	16,071	– 8.9
Total or mean	*90,087*	*75,405*	*67,037*	*–11.1*
Saline				
Gallatin	9,818	7,638	7,418	– 2.9
Hamilton	12,256	10,010	8,665	–13.4
Saline	33,420	26,227	25,721	– 1.9
Total or mean	*55,494*	*43,875*	*41,804*	*– 4.7*
Little Wabash				
Clay	17,445	15,815	14,735	– 6.8
Edwards	9,056	7,940	7,090	–10.7
Effingham	21,675	23,107	24,608	+ 6.5
Richland	16,889	16,299	16,829	+ 3.3
Wabash	14,651	14,047	12,841	– 8.6
Wayne	20,933	19,008	17,004	–10.5
White	20,935	19,373	17,312	–10.6
Total or mean	*121,584*	*115,589*	*110,419*	*– 4.5*
Embarras				
Clark	17,362	16,546	16,216	– 2.0
Coles	40,328	42,860	47,815	+11.6
Crawford	21,137	20,751	19,824	– 4.5
Cumberland	10,496	9,936	9,772	– 1.7
Douglas	16,706	19,243	18,997	– 1.3
Edgar	23,407	22,550	21,591	– 4.3
Jasper	12,266	11,346	10,741	– 5.3
Lawrence	20,539	18,540	17,522	– 5.5
Total or mean	*162,241*	*161,772*	*162,478*	*+ 0.04*

Table 9.—Continued.

Watershed and County	1950[a]	1960[b]	1970[c]	Percentage of Change, 1960–1970
Vermilion				
Champaign	106,100	132,436	163,281	+23.3
Ford	15,901	16,606	16,382	− 1.3
Vermilion	87,779	96,176	97,047	+ 0.09
Total or mean	*209,780*	*245,218*	*276,710*	*+12.8*
Iroquois				
Iroquois	32,348	33,562	33,532	− 0.09
Kankakee	73,524	92,063	97,250	+ 5.6
Total or mean	*105,872*	*125,625*	*130,782*	*+ 4.1*

[a] New York World Telegram & The Sun (1954).
[b] New York World Telegram & The Sun (1961).
[c] Newspaper Enterprise Association, Inc. (1975).

A bottomland forest measured in St. Clair County showed that silver maple, hackberry, elms, ashes, box elder, overcup oak, big shellbark hickory, pin oak, pecan, and bur oak dominated the tree stratum (Table 4). In general, forests along the Kaskaskia and other southern Illinois rivers contain more species of oak and hickory than do their counterparts along rivers in central and northern Illinois (Telford 1926).

The virgin bottomland forests persisted along the Kaskaskia River longer than did those in most other regions of Illinois. As late as 1924 Telford (1926) reported that one-fourth of all the old-growth bottomland forests in the entire state grew along the Kaskaskia. A few of these old stands still exist south of Carlyle Lake (J. White, Illinois Natural Areas Inventory, personal communication, 1975).

About 50 percent of the region was forested in 1800; by 1962 only about 16 percent was forested (Table 3). Gray squirrels were abundant in the Kaskaskia basin in 1800, constituting an estimated 79.7 percent of the squirrel population (Table 5). They are still common throughout the basin except where the forests have been extensively altered or removed (Fig. 10). Today gray squirrels are totally absent only in areas that were predominantly prairie before settlement, northern Montgomery, Shelby, and Moultrie counties (J. White, unpublished *Presettlement Vegetation Atlas of Illinois*) (Fig. 10).

Gray squirrels comprise nearly half or more of the squirrel harvests from Clinton, Fayette, Marion, Monroe, and Randolph counties (Table 6). In 1972–1974 they made up 46.8 percent of 295 squirrels harvested on the Stephen A. Forbes State Park in Marion County. Gray squirrels are abundant in Granite City (Madison County) and East St. Louis and Belleville (St. Clair County).

In 1942 it was thought that gray squirrels were confined to the immediate vicinity of the Kaskaskia River (Fig. 3). However, we believe that Brown & Yeager (1945) underestimated the distribution of gray squirrels in the basin (Fig. 10). Since 1942 the removal of forests has reduced gray squirrel populations in the uplands away from the Kaskaskia River in St. Clair and Monroe counties (Fig. 10).

The greatest threat to the gray squirrel in the basin has been reservoir construction. The construction of Carlyle (26,000 acres) and Shelbyville (11,100 acres) reservoirs destroyed thousands of acres of bottomland forests occupied by gray squirrels. In addition, the record high floodwaters experienced in the basin between 1973 and 1974 killed thousands of acres of upland forests surrounding both reservoirs (Bell & Johnson 1974). Leisure homes and recreational facilities and pursuits on both public and private lands around the reservoirs have also intruded upon the forests. As the remaining forests are opened up and reduced in size, fox squirrels can be expected to increase in abundance. In March 1976 and 1977, gray squirrels made up 42.3 percent of 52 squirrels live-trapped in two pole-sized upland stands of oak-hickory adjacent to Lake Shelbyville.

Only 24.6 percent of the existing forests in the region are pastured, mostly in the northern counties (Table 8). Channelization has occurred on an average of 47 miles of stream per county, with Montgomery and Monroe counties the most affected (Table 8). Strip-mining for coal is important only in St. Clair and Randolph counties, where nearly 18,000 acres have been mined. Only 488 of these strip-mined acres now support maturing forests (Table 8).

Human populations are increasing in the basin, particularly in Madison County near St. Louis and in Monroe and Clinton counties (Table 9).

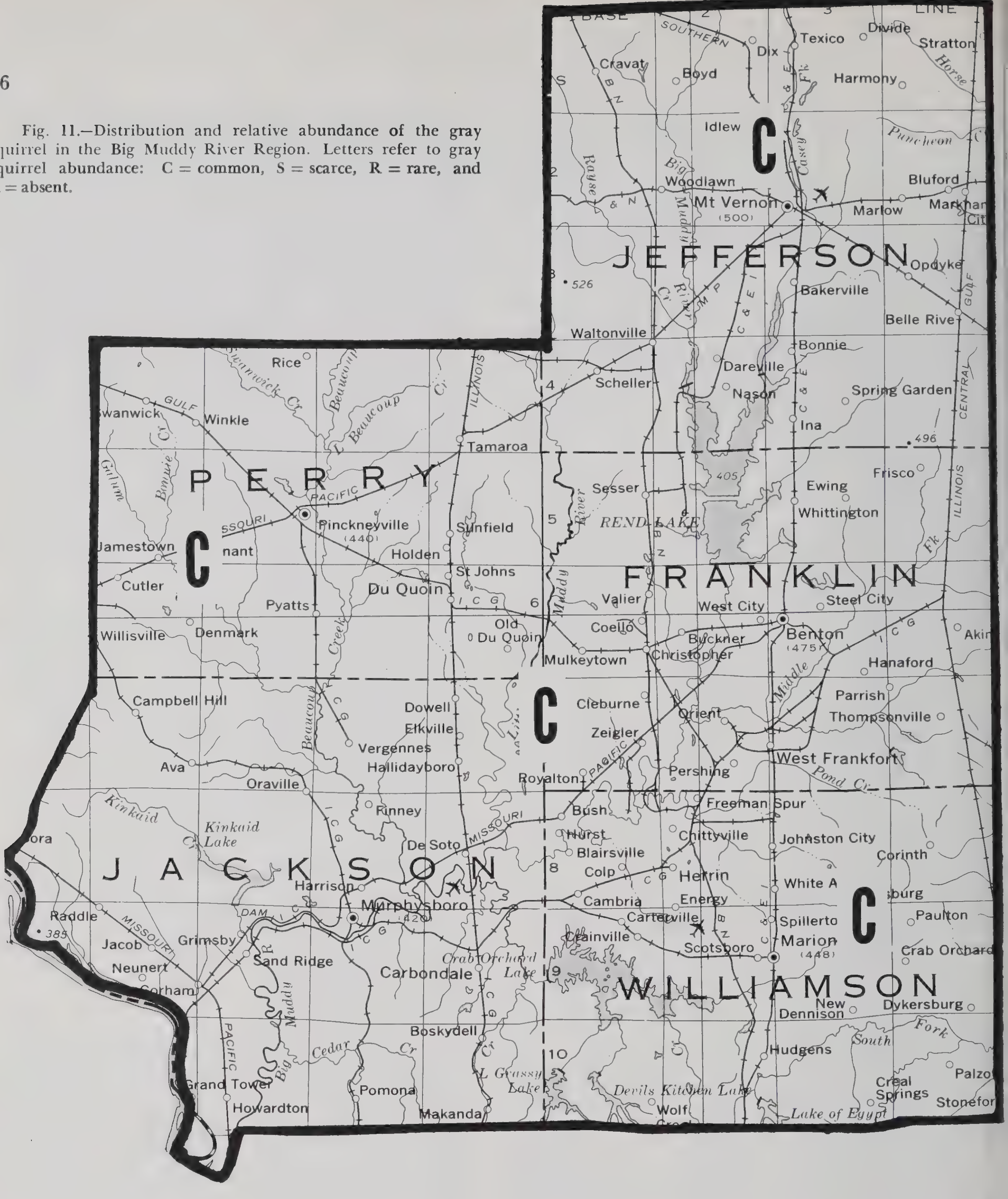
Huntable populations of gray squirrels appear assured in the region for the foreseeable future although gray squirrels will undoubtedly continue to decline in the upper basin as human activities remove or modify the remaining forests.

Big Muddy River Region

The Big Muddy basin located in southwest Illinois encompasses five counties (Fig. 11). The topography is characterized by gently undulating hills in the north and west; low relief, wide valleys, and well-developed upland in the east; and more rugged, well-defined valleys in the south (Big Muddy River Basin Coordinating Committee 1971). Local relief seldom exceeds 100 feet.

A bottomland forest located along the Little Muddy River in Jackson County showed pin oak, silver maple, big shellbark hickory, elms, ashes, swamp white oak, and post oak as the most important species (Table 4). The large number of mature oaks and hickories contributes to the widespread abundance of the gray squirrel throughout the Big Muddy basin (Fig. 11). The upland forests are predominately mixtures of oak and hickory with smaller numbers of sugar maple, basswood, ashes, tulip tree, and American beech on the better sites (Telford 1926).

Fig. 11.—Distribution and relative abundance of the gray squirrel in the Big Muddy River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.



At the time of settlement the basin was 87 percent forested. Although a slight increase (2.0 percent) in forest land occurred between 1948 and 1962, there has been an overall decline of 71.1 percent since 1800, leaving 25 percent of the region in forest by 1962 (Table 3).

Gray squirrels make up about 50 percent of the squirrel population and may be increasing throughout the basin (Table 6). They are most abundant in Jackson and Williamson counties.

Human densities have virtually stabilized in the Big Muddy River basin since 1950 (Table 9) but are beginning to increase around Murphysboro and Carbondale. Rend Lake (18,900 acres) and Lake Kincaid (3,800 acres) have flooded and destroyed several thousand acres of the gray squirrels' bottomland habitat.

Although pasturing of forests and stream channelization are not problems for gray squirrels in this region, strip-mining for coal has disturbed many acres (Table 8). More than 38,000 acres had been strip-mined by 1971, with Perry, Jackson, and Williamson counties extensively affected (Table 8). Only about 1,800 acres have succeeded to a maturing forest capable of supporting gray squirrels. The increasing demand for coal will probably result in many more acres of strip-mined land, and it may be many years, if ever, before gray squirrels reoccupy the strip-mined areas.

There are several extensive forests in public ownership in the Big Muddy River Region that, properly managed, should insure the continued presence of gray squirrels. The 43,000-acre Crab Orchard National Wildlife Refuge, the federally owned forests in Jackson and Williamson counties, and the forests surrounding Rend Lake in Franklin and Jefferson counties should all continue to support abundant populations of gray squirrels.

Shawnee Hills Region

The Shawnee Hills Region comprises the seven southernmost counties in Illinois (Fig. 12). It is a complexly dissected upland that extends across the southern tip of Illinois from Fountain Bluff on the Mississippi River to the Shawneetown Hills near the mouth of the Wabash River. These uplands escaped Pleistocene glaciation. The Greater Shawnee Hills form a band along the northern edge of the basin and consist of massive Pennsylvanian-aged sandstones that dip northward toward the Illinois River basin (Mohlenbrock 1975). The north slope of the Greater Shawnee Hills is relatively gentle, but the south slope consists of many scarps, cliffs, and overhanging bluffs. This section averages only 10 miles in width and grades into the Lesser Shawnee Hills section to the south. The Lesser Shawnee Hills are underlain by Mississippian-aged limestones and sandstones. Their elevation averages about 200 feet lower than that of the Greater Shawnee Hills. The soils of the Shawnee Hills Region are derived mainly from loess. South of the Shawnee Hills lies the coastal plain, a region of swampy forested bottomlands and low clay and gravel hills (Mohlenbrock 1975).

A bottomland stand in Union County contained silver maple, sweet gum, elms, and pin oak as the dominant tree species (Table 4). A second bottomland stand in Johnson County was dominated by sweet gum, ashes, elms, swamp chestnut oak, box elder, and red maple (Table 4). In an upland forest on a mesic site in Pope County, northern red oak, sugar maple, hickories, American beech, and white oak were dominant in the tree stratum (Table 4).

Upland forests of the region have not fared well in this century. Miller & Fuller (1921:96–98) documented the abuses endured by these forests in Alexander County. Their description applies equally well to most of the forests of the entire state. In 1920 they found none of the forests in primitive condition. Most lands originally mapped as forest were so completely cut over that no merchantable timber remained. Tulip trees were cut first, between 1880 and 1890, followed by the larger oaks. Finally, the small oaks were cut for railroad ties. The forests were then grazed and burned so often that the species valuable for timber products were killed, and the stands converted to a black oak-hickory type (Miller & Fuller 1921:96–99).

In the 1930's the United States government began buying the abandoned hill farms in the region, and today the Shawnee National Forest contains 230,000 acres of forest, most of which support gray squirrels. Under protection, the upland forests have slowly recovered, and production of quality hardwood has increased, especially white oak, black walnut, and tulip tree (U.S. Department of Agriculture Forest Service 1969). However, this increase in forest land has not been uniform in the region. Although the upland forests have increased (Table 3), the bottomland forests have declined. For example, there were 15,802 acres of mature lowland forest in 1942 in a 30-square-mile tract of bottomland encompassing portions of Cache and Vienna townships, Johnson County, and Karnak, Logan, and Benton townships, Massac County. By 1966 this forest had been reduced to 5,312 acres, and only 3,584 acres were left in 1971, a 77.3 percent decline in only 29 years (J. and R. Graber, Illinois Natural History Survey, unpublished data). These mature bottomlands have the best soils in the region and, when properly drained, are highly productive for row crops.

The Shawnee Hills and associated bottomlands were almost entirely forested in 1800 (Table 3) and even today remain about 40 percent forested. Forests in Pope, Hardin, and Johnson counties (mostly upland forests) have increased since 1948, but in Massac, Union, and Pulaski counties, where extensive tracts of bottomland forests occur, forest acreage has declined slightly (Table 3).

Gray squirrels are abundant throughout the Shawnee Hills with the exception of two floodplains, extensively cleared for agricultural use, adjacent to the Ohio and Mississippi rivers (Fig. 12). Fox squirrels were probably comparatively rare in the Shawnee Hills

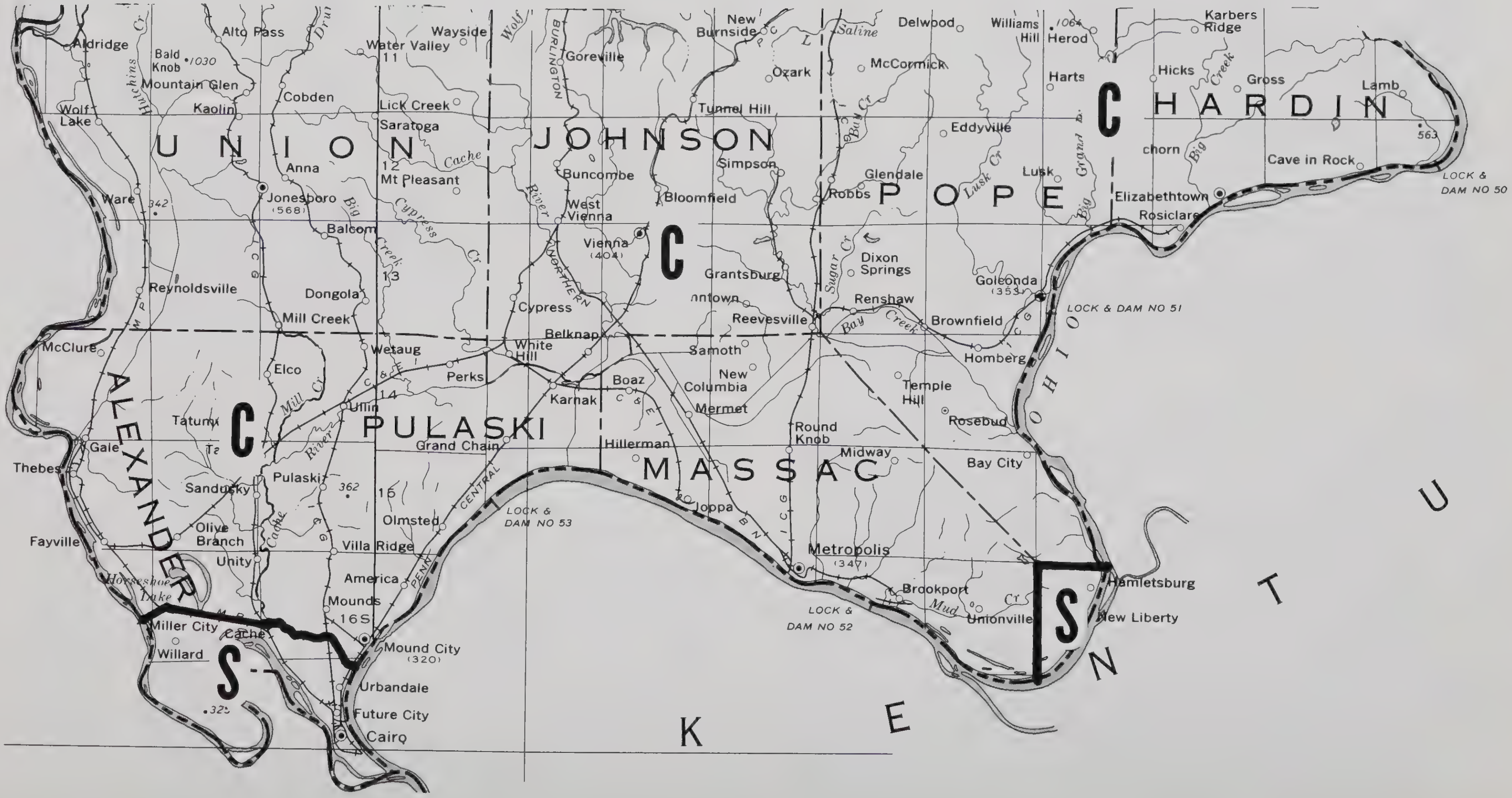


Fig. 12.–Distribution and relative abundance of the gray squirrel in the Shawnee Hills Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

in the early 19th century (Table 5), and even today gray squirrels constitute about two-thirds of the squirrel harvest (Table 6). In a few of the protected bottomland forests, such as Horseshoe Lake Conservation Area in Alexander County, the squirrel population is made up almost entirely of gray squirrels. On Horseshoe Lake Island gray squirrels may reach their highest density in Illinois (J. and R. Graber, personal communication, 1973–1974).

Human populations declined in every county of the Shawnee Hills Region except Johnson between 1960 and 1970 (Table 9), but this trend is not likely to continue. More and more leisure homes are being built throughout the region. Private forests are being cleared for pastures, often on slopes that should remain tree covered. Funds from the U.S. Department of Agriculture are used for pasture improvement, but only in Johnson County is pasturing of private forests a serious problem (Table 8). In the counties of this region, 57.8 miles (average) of streams have been channelized.

Survival of the gray squirrel in the Shawnee Hills Region seems assured because of the large area of both upland and bottomland forests now in public ownership. Of the nearly 300,000 acres of publicly owned forests, almost all support gray squirrels.

Saline River Region

Most of this three-county basin (Fig. 13) has been glaciated and is characterized by low relief and broad alluvial valleys along the larger streams. The southern edge of the region was not glaciated and forms a portion of the Shawnee Hills, a dissected upland of rugged relief. The rivers are low in gradient, and the wide floodplains that supported large tracts of bottomland timber were formerly subject to extensive flooding. Soils are derived from loess and glacial outwash.

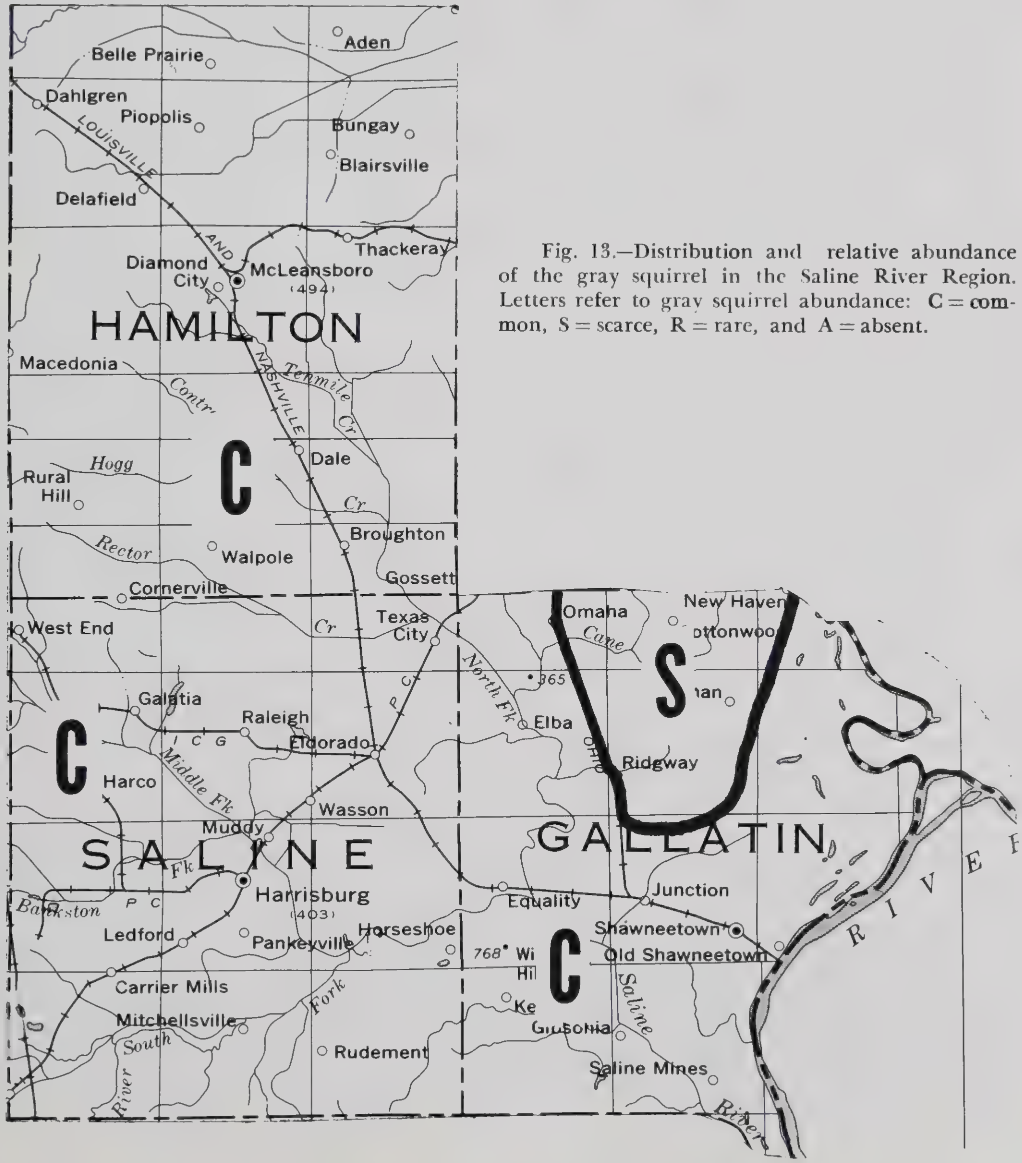


Fig. 13.—Distribution and relative abundance of the gray squirrel in the Saline River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

The upland forests are predominately oaks and hickories. A forest sampled along the first terrace of the Middle Fork of the Saline River was dominated by ashes, northern red oak, sweet gum, black oak, elms, and pin oak (Table 4).

Gray squirrels are generally common throughout the basin except where there has been extensive clearing of forests (Fig. 13). The basin was nearly 100 percent forested in 1800—the most heavily forested region in Illinois (Table 3). By 1962 only about 21.8 percent of the area was still in forest, mostly on bottomlands adjacent to the Saline River and its tributaries (Table 3). The proportion of gray squirrels in the harvest declined from an estimated 100 percent in 1800 to 56.6 percent in 1956–1957 (Table 5). Today, gray squirrels make up about 50 percent of the squirrel kill from this region (Table 6), with Hamilton County contributing the highest proportion of gray squirrels to the harvest (Table 6).

Although the human population of the region has declined in recent years (Table 9), drainage has been intensive (Table 8). Channelization is now under way or planned for most of the Saline River and its principal tributaries. Dredging of the river would permit barge traffic to move coal from the extensive deposits in Saline and Gallatin counties to markets downriver. Once the principal rivers are channelized, the extensive bottomland forests adjacent to the rivers are doomed to be cleared, drained, and farmed. It is unfortunate that so little of the present forest land in the Saline basin is in public ownership. The almost certain decline of the gray squirrel in the basin in future years will depend largely on how much bottomland forest is cleared. The significant decrease ($P < 0.01$) in the proportion of gray squirrels in the harvests in 1971–1973, compared with that in 1956–1957 (Table 6), indicates that gray squirrels may already be declining in the basin.

Little Wabash River Region

The Little Wabash River Region encompasses a seven-county area in southeastern Illinois (Fig. 14). The river begins near Mattoon in Coles County and flows southeast about 120 miles to its junction with the Wabash River in White County. The uplands and bottomlands are both flat, with steep, rolling land between them. Local relief varies as much as 100 feet in the lower portion of the basin (Barker et al. 1967*a*). Upland soils are generally derived from a thin loess over till or outwash. Bottomland soils are of recent alluvium over lacustrine deposits (Barker et al. 1967*a*).

A floodplain forest surveyed in Wabash County was dominated by elms, hackberry, silver maple, sweet gum, box elder, bur oak, and pecan (Table 4). The upland forests were dominated by oaks and hickories—post oak and blackjack oak on the poorest soils and black, white, shingle, and northern red oaks, basswood, hickories, ashes, and sugar maple on the better upland sites (Mohlenbrock 1975).

The basin was about 60 percent forested in 1800 but by 1962 only about 15 percent of the land area was still forested (Table 3). On a percentage basis forest acreage is nearly equal in each county throughout the basin (Table 3).

Gray squirrels were the most abundant squirrel in the basin in 1800 (Table 5), but by 1956–1957 they constituted only about 30 percent of the squirrel harvest (Table 6). Today, gray squirrels are scarce in portions of the basin, particularly in the upland forest away from the major streams (Fig. 14). Upland forest have been extensively cleared for agricultural purposes. Gray squirrels are most common in the centra and southern portions of the region.

The proportionate harvest of gray squirrels increased in every county in the basin in 1971–1973 a compared with that of 1956–1957 (Table 6). Thi significant increase ($P < 0.01$) in the proportionate gray squirrel harvest may reflect the 1.4 percent increase in forest land that occurred in the basin between 1948 and 1962 (Table 3). More recent estimates o forest cover are not available.

The pasturing of forests is not a serious problem in the Little Wabash basin, at least compared with more northern watersheds in Illinois (Table 8). Stream and river channelization is not a major difficulty a this time, and coal deposits are not of commercia importance (Table 8).

Human populations have generally declined ove most of the basin, with only Effingham and Richland counties showing increases between 1960 and 1970 (Table 9). Population projections do not indicat large increases in human population for the region (Barker et al. 1967*a*). Even though most of the forest are privately owned, huntable gray squirrel populations should persist for the foreseeable future.

Also present in the Little Wabash Region are the famed "white" gray squirrels of Olney, Illinois. These squirrels are descendants of one or more white squirrels originally captured near Sumner (Lawrence County) (Thomas 1971). J. C. Banks of Olney bough a pair of these captive squirrels and released them in the town in 1902. The number of albino gray squirrel now in Olney is estimated at 1,000 (Thomas 1971).

Embarras River Region

The Embarras River originates in the upland prairies of southern Champaign County and flow through the level prairies of northern Douglas County (Fig. 15). The river then flows as a sluggish meandering stream across the level uplands and is fed by numerous low-gradient tributaries. Near the Coles Douglas county line the river drops abruptly to form a steep-walled V-shaped valley 50–70 feet deep tha

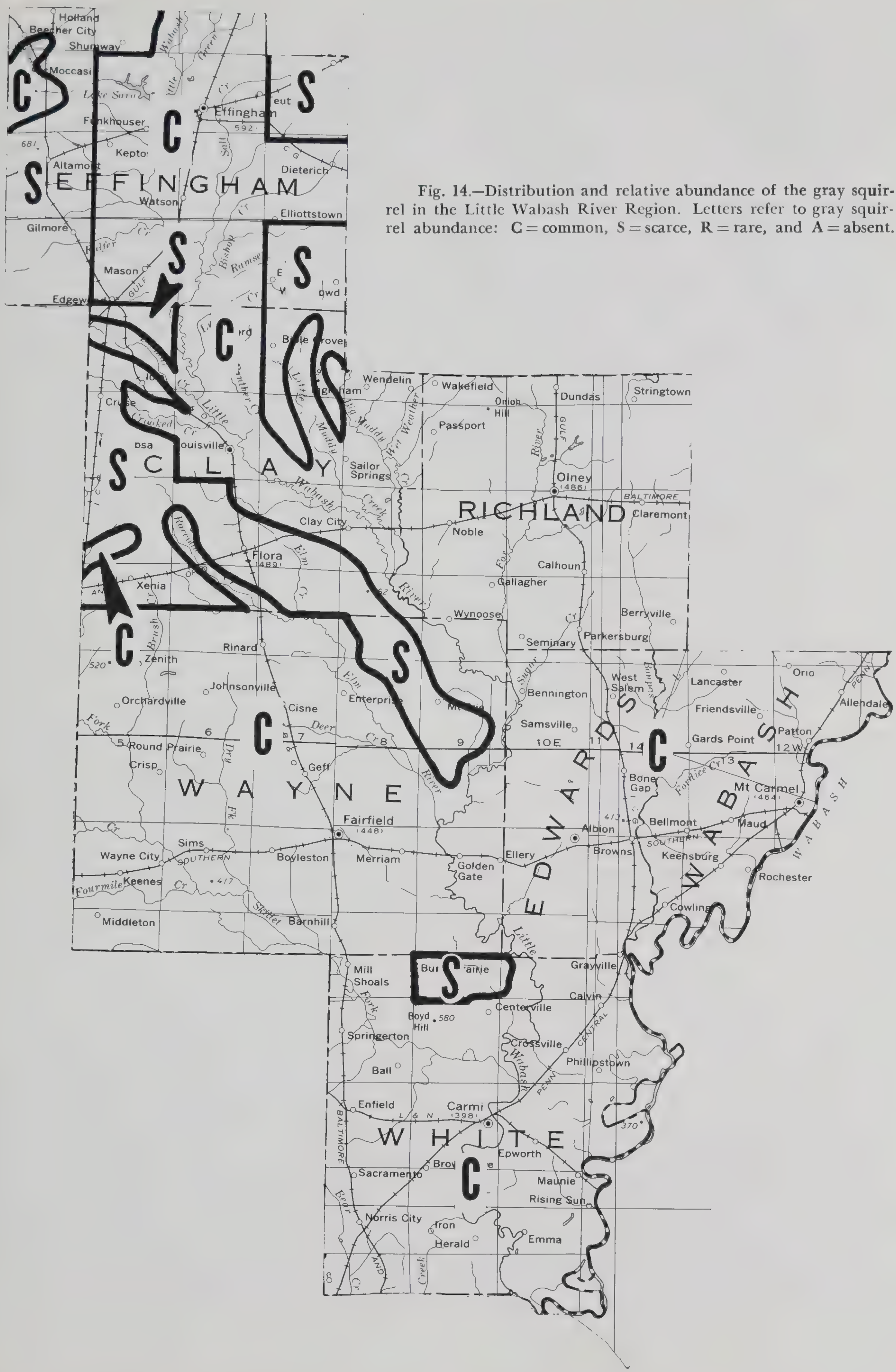


Fig. 14.—Distribution and relative abundance of the gray squirrel in the Little Wabash River Region. Letters refer to gray squirrel abundance: **C** = common, **S** = scarce, **R** = rare, and **A** = absent.

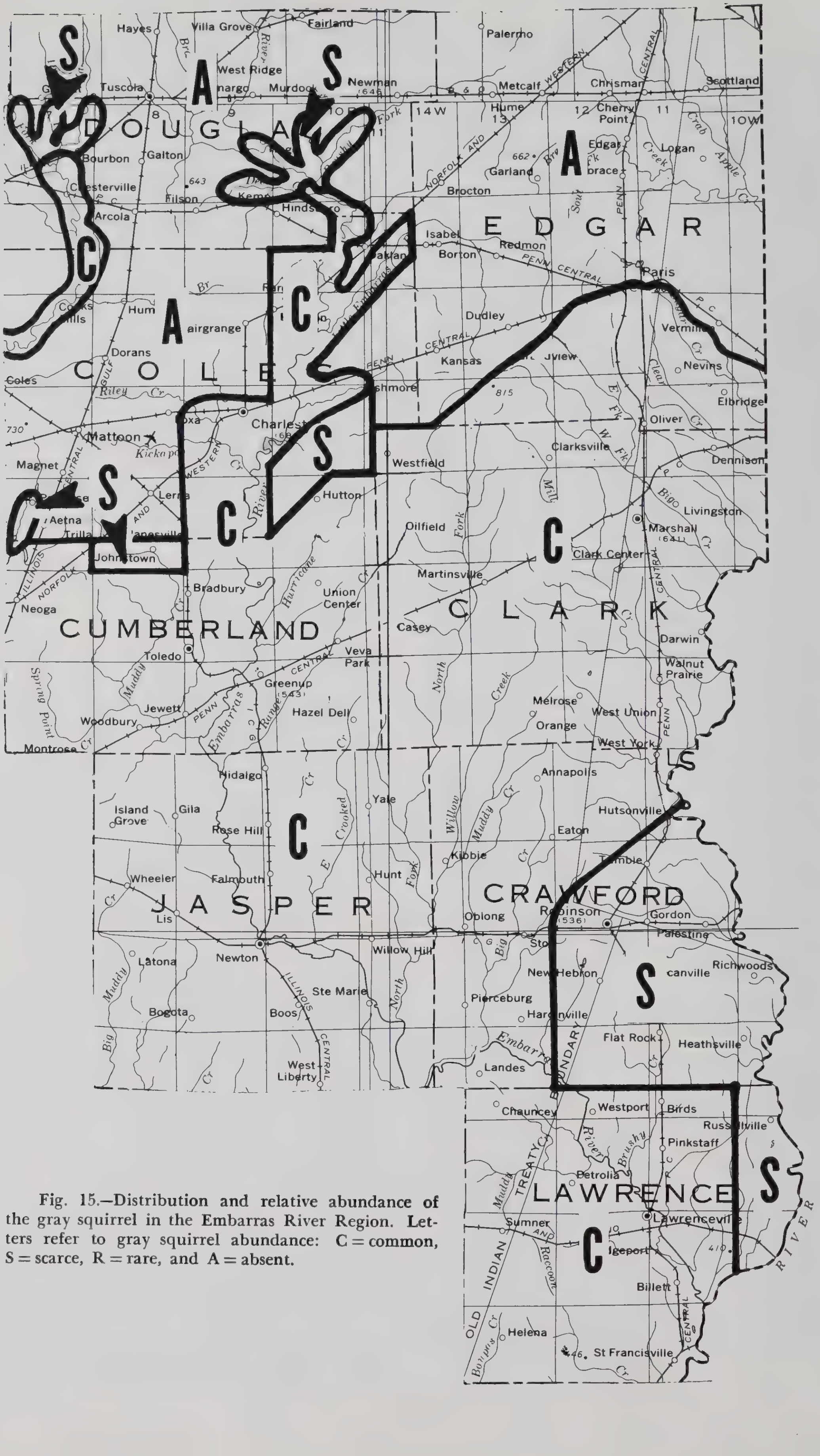


Fig. 15.—Distribution and relative abundance of the gray squirrel in the Embarras River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

extends southward for approximately 50 miles (Telford 1926).

In preglacial times the Embarras River flowed through the Pennsylvanian Lowland and had a valley that ranged from 1 to 5 miles in width. This drainage system was altered by glaciation, and the Embarras River now crosses three distinct physiographic divisions. The river originates on the Bloomington Ridged Plain, composed of glacial till; crosses the Shelbyville moraine into the Springfield Plain; and finally, in southern Crawford County, crosses the Mount Vernon hill country (Mohlenbrock 1975). The topography varies from hilly terrain in the upper reaches to flat to gently rolling terrain along the lower river. The valley is less than a mile wide in northern Cumberland County but is 3–4 miles wide in the lower reaches. Soils are derived from loess, glacial till, and outwash.

In 1800 the Embarras River basin supported one of the largest stands of hardwood forest in the eastern United States (Winters 1969). Lawrence, Clark, and Crawford counties were about 75 percent forest although, as a whole, the basin was over half prairie in 1800 (Table 3). Today only about 12 percent of the basin is forested, and Clark, Crawford, and Lawrence counties are still among the most forested counties in the region (Table 3).

In a second-growth upland forest surveyed in Edgar County, where gray squirrels are absent, osage orange, black walnut, honey locust, shagbark hickory, shingle oak, and elms were the dominant tree species (Table 4). A bottomland forest along the Embarras in Coles County contained silver maple, cottonwood, box elder, willows, and elms as the most important tree species (Crites & Ebinger 1969) (Table 4).

An estimated 74 percent of the squirrel population in this region was composed of gray squirrels in 1800 (Table 5), compared with about 20 percent grays in recent squirrel harvests (Table 6). The remains of squirrels found at archeological sites indicate that gray squirrels constituted nearly 100 percent of the squirrel populations in prehistoric Crawford and Lawrence counties (Table 2).

Gray squirrels are proportionately more abundant today in Jasper, Cumberland, and Lawrence counties (Table 6) than in the remaining counties. They are absent in the upper Embarras River basin north of the Douglas County Conservation Area but are generally distributed and abundant from there south to the mouth of the Embarras River. There are none in the uplands of Coles County and in central and northern Edgar County. These upland areas were mostly prairie in the 19th century and probably never have harbored many gray squirrels during historic times. Gray squirrel habitat has also been reduced along the Wabash River in Crawford and Lawrence counties (Fig. 15) because of widespread removal of the bottomland forests for agricultural purposes.

The Embarras River is still relatively undisturbed throughout much of its course although stream channelization has been extensive in the upper Embarras basin, particularly in Douglas and Edgar counties (Table 8). The removal of riparian forests during channelization eliminated gray squirrels from most of the upper river in those counties. Nearly half of the remaining forests are pastured, further reducing the quality of forest habitat available to gray squirrels (Table 8).

Human densities have remained relatively stable in the basin since 1950 (Table 9). Only Coles County increased in population between 1960 and 1970.

In the upper basin gray squirrels will continue to decline as forests are removed or degraded by man's activities. In the lower basin occupied gray squirrel range is more extensive, and many forests will continue to harbor gray squirrels for the foreseeable future.

Vermilion River Region

The Vermilion River Region comprises three counties in east-central Illinois (Fig. 16). The Vermilion basin is essentially a sequence of low moraines and level plains, left by the retreat of glacial ice, through which the principal streams have cut downward to their present levels. Steep slopes are confined to the valley walls of the larger streams. Near Danville local relief changes as much as 100 feet along the river. Soils developed on loess over till, outwash, or lake-bed deposits. The bottomlands are alluvial, silt loams (Barker et al. 1967*b*).

In an upland forest, where gray squirrels are common, in McKendree Township, Vermilion County, our survey showed that black oak, various hickories, white oak, sugar maple, and American beech were the dominant trees (Table 4). In a forest in which gray squirrels are absent in Grant Township, Vermilion County, osage orange, shagbark hickory, box elder, hawthorns, and black oak were dominant in the tree stratum (Table 4). Bottomland forests throughout the basin are dominated by silver maple, ashes, elms, cottonwood, and some willows.

Gray squirrels are common in the cities of Champaign-Urbana, St. Joseph, Rantoul, and in Lake of the Woods Park in Champaign County (Fig. 16). They are also present in both Brownfield Woods and Trelease Woods, 24.2-ha old-growth forests located just northeast of Urbana. They are locally rare to scarce along the Salt Fork of the Vermilion River between Urbana and St. Joseph in Champaign County (Fig. 16). Their presence along the Salt Fork and south of Lake of the Woods Park on the Sangamon River may represent a recent expansion of range, as Wood (1910) reported no gray squirrels present in the rural areas of Champaign County in the early 20th century.

In Vermilion County gray squirrels are scarce in Danville but are locally abundant downstream from

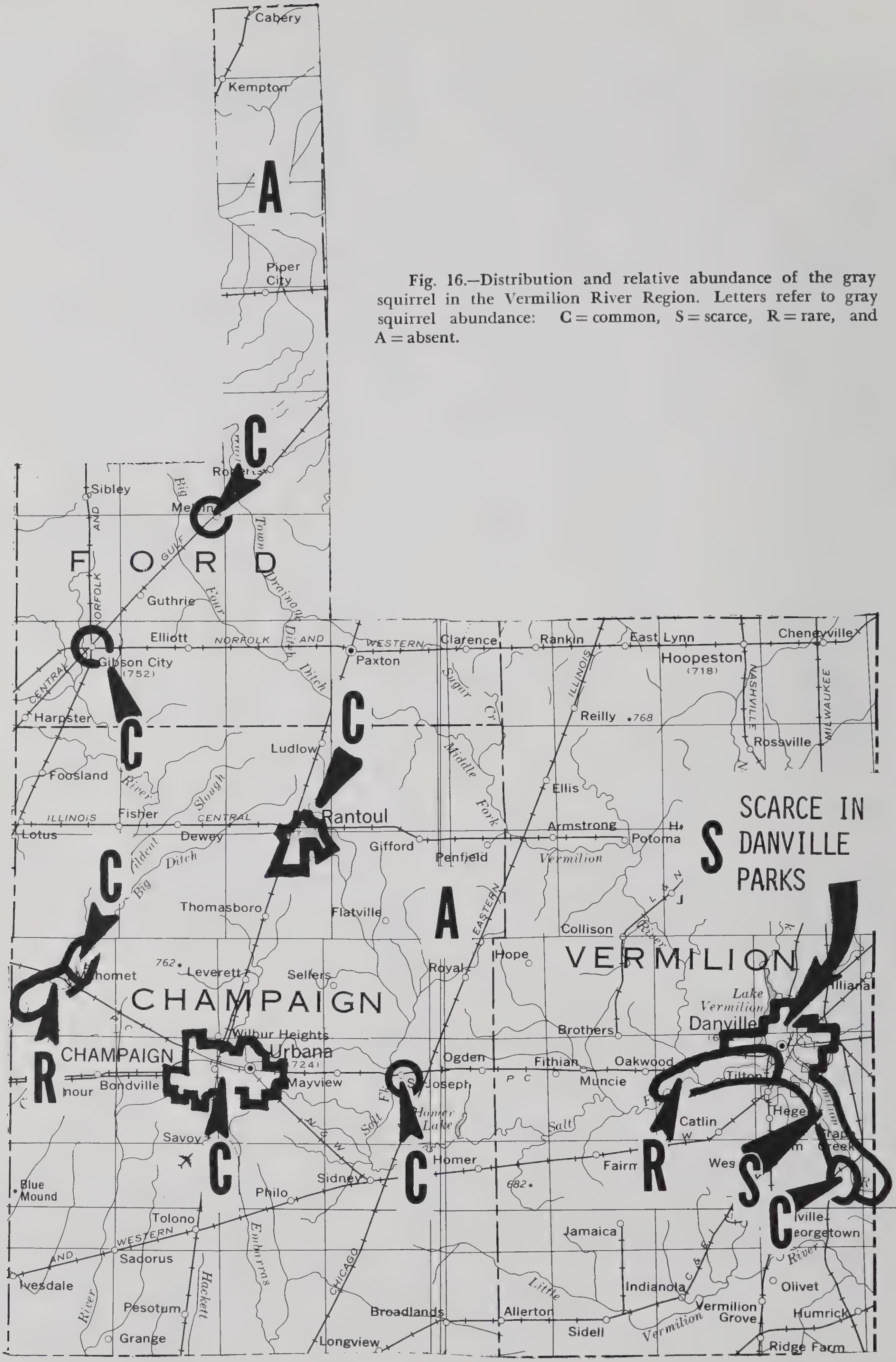


Fig. 16.—Distribution and relative abundance of the gray squirrel in the Vermilion River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

Danville along the Vermilion River. Gray squirrels make up about 10 percent of the squirrel population below Danville (Nixon & Havera, unpublished data) but may be more abundant in localized areas. On a 12.1-ha upland forest of mixed hardwoods at Forest Glen County Preserve, 7 miles southeast of Danville, 38 of 62 livetrap captures (61.3 percent) were gray squirrels. On a similar 12.1-ha tract only 400 m away, 7 of 46 captures (15.2 percent) were gray squirrels.

The 1942 survey of gray squirrel distribution (Brown & Yeager 1945) showed gray squirrels present along the upper reaches of the Middle Fork River in Ford County and along the lower Vermilion River adjacent to Indiana in Vermilion County (Fig. 3). Since 1942 gray squirrels have been extirpated from areas along the upper Middle Fork and are found only in the cities of Melvin and Gibson City in Ford County. Stream channelization began early in this region, a practice that removed what was often the only forested habitat in this prairie-dominated area. The extensive stream channelization in both Champaign and Ford counties (Table 8) may have been a factor in reducing the range of the gray squirrel in those counties.

In recent years gray squirrels have constituted only about 6 percent of the squirrel harvest from the Vermilion basin (Table 6). We suspect that reports of gray squirrels killed in Ford and Champaign counties represent hunter error or illegal hunting on reserves, because gray squirrels are virtually nonexistent in areas legally open to hunting in these counties (Fig. 16). According to landowners along the Little Vermilion River in southwest Vermilion County, gray squirrels were present in Elwood Township until about 1960, when extensive timber cutting decimated the riparian forests in the township. Mohr's (1941) sighting of a gray squirrel in this drainage in the 1940's confirms the landowners' observations. He (Mohr, personal communication, 1975) also sighted a gray squirrel in 1940 near Oakwood (Vermilion County) in a formerly strip-mined area. They are not present in this area today. The recent purchase of portions of the lower Vermilion River valley by public agencies should protect the area from land clearing, grazing, and indiscriminate timber cutting and thus help to maintain gray squirrel populations along the Vermilion River south of Danville.

Human populations are increasing rapidly in Champaign County (Table 9) but fortunately have remained relatively stable in Vermilion County, where most of the gray squirrel habitat in the Vermilion River Region exists today.

Iroquois River Region

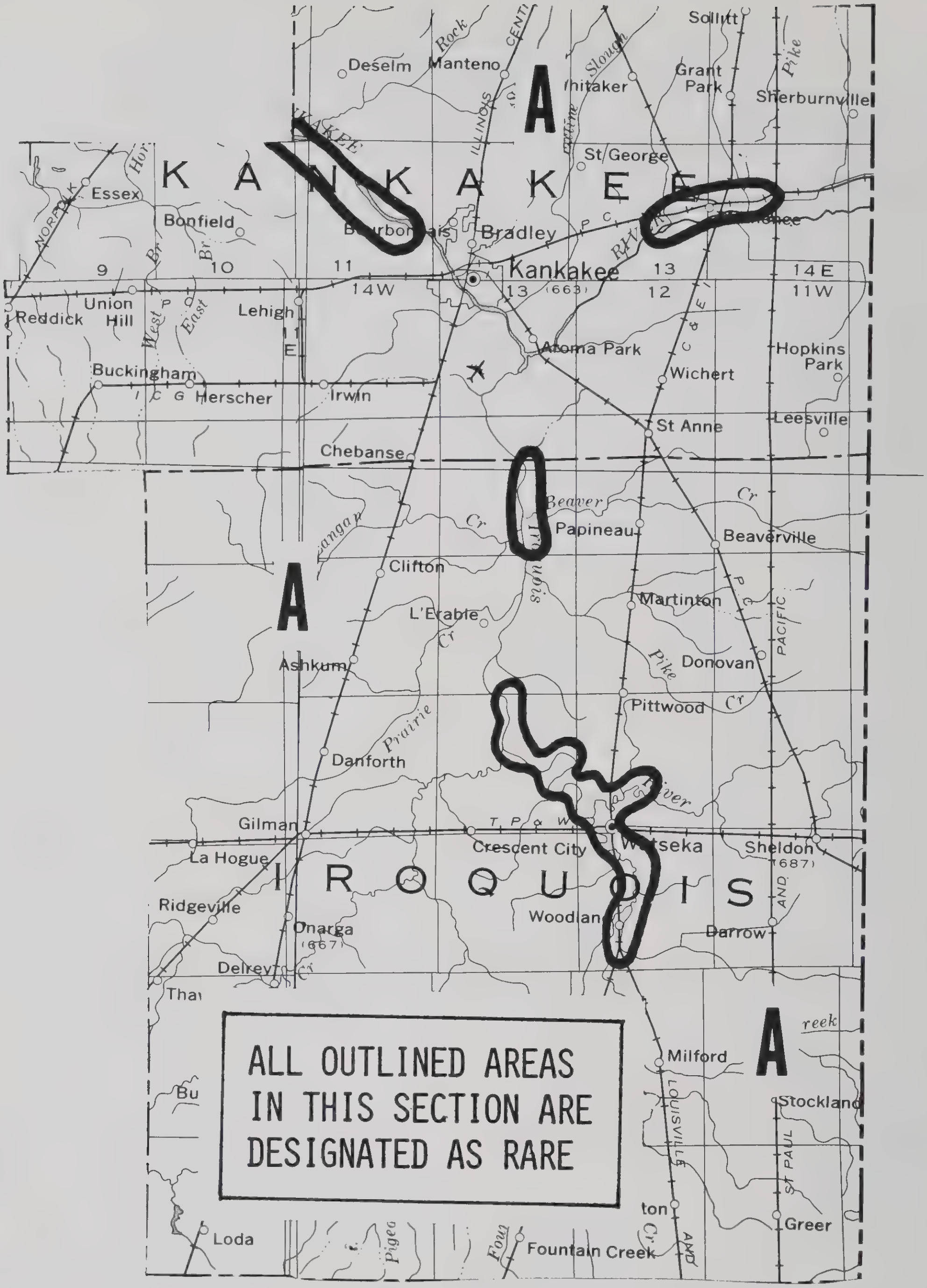
The Iroquois River Region, a two-county area (Fig. 17), is drained by the Iroquois River and a portion of the Kankakee River, both of which arise in western Indiana. Both rivers have relatively low gradients and flow through a mantle of unconsolidated glacial deposits (Barker et al. 1967*c*). Sand dunes are common in southeastern Kankakee and northeastern Iroquois counties. The topography is nearly flat in old glacial lake beds but is rolling and locally steep along the sides of the numerous moraines that occur throughout the basin (Barker et al. 1967*c*). Forests are confined to the floodplains and their associated bluffs along the major rivers and streams.

Only 6.1 percent of the basin was forested in 1800 (Table 3). Today, only 26,700 acres of forest remain—about 2.3 percent of the land area (Table 3). The tree stratum of a bottomland forest in Iroquois County was dominated by ashes, elms, silver maple, basswood, and hackberry (Table 4). The dominant trees in an upland forest in Iroquois County were black oak, white oak, northern red oak, black cherry, and ashes (Table 4).

Gray squirrels are now considered present but rare north and south of Watseka along Sugar Creek, along the Iroquois River just south of the Kankakee County line, along the Kankakee River east and west of Momence, and northwest of Bourbonnais along the Kankakee River to the Will County line (Fig. 17). Gray squirrels are occasionally seen by park personnel at Kankakee River State Park southeast of the Kankakee-Will county line (R. Fredericks, personal communication, 1974). However, during 1971–1973 no grays were among the 300 squirrels reported shot by hunters in this park. Gray squirrels are occasionally shot by hunters in Kankakee County but only rarely in Iroquois County (Table 6). In 1942 gray squirrels were thought to have been extirpated from these two counties (Brown & Yeager 1945) (Fig. 3), but it seems likely that the 1942 survey missed the four small, isolated populations mentioned here.

Streams in these two counties have been extensively modified by channelization (Table 8), and riparian forests have been removed or converted to forests of osage orange, box elder, hawthorn, ashes, and elms. Forests have been totally removed along many of the smaller streams and have been replaced by grasses and forbs. Between 1960 and 1970 human densities remained stable in Iroquois County but increased about 6 percent in Kankakee County (Table 9).

Gray squirrels will probably continue to be rare in the Iroquois basin. The continued removal of forests or overcutting of the forests where grays presently occur will very likely extirpate them. Only the 2,000-acre Kankakee River State Park protects any appreciable amount of forest in the basin, and although gray squirrels are present in the park, they have not recently increased to any degree and persist at a very low density (R. Fredericks, personal communication, 1974).



ALL OUTLINED AREAS
IN THIS SECTION ARE
DESIGNATED AS RARE

Fig. 17.—Distribution and relative abundance of the gray squirrel in the Iroquois River Region. Letters refer to gray squirrel abundance: C = common, S = scarce, R = rare, and A = absent.

CHARACTERISTICS OF GRAY SQUIRREL HABITAT

We found a highly significant relationship between the percentages of gray squirrels killed in each county *(Y)* in 1956–1957 and the percentage of each county forested *(X)* in 1962 ($r = +0.82$, $R^2 = 0.67$, df = 100) ($P < 0.001$). This analysis suggests that about two-thirds of the difference in the numbers of gray squirrels harvested in various counties is associated with the proportion of forested land in the counties where they are hunted. On the basis of this relationship, we conclude that a county must be 30 percent forested t attain a squirrel harvest composed 50 percent of gra squirrels.

We tried square root and logarithmic transformations of both independent and dependent variable but were unable to increase materially the value c the correlation coefficient.

The proportion of gray squirrels in the 1956–195 squirrel harvest in each county *(Y)* was also tested fo association with the percentage of forest land that wa grazed by livestock in each county (Illinois Conserva tion Needs Commission 1970) and with the amount of hardwood sawtimber (dbh of 4.72 cm or more) remaining in each county (Essex & Gansner 1965:40). The correlation between the proportionate harvest of gray squirrels and the percentage of grazed forest land was negative but relatively low ($r = -0.42$, $P > 0.05$, df = 100). A significant positive correlation ($r = +0.61$, $P < 0.01$, df = 73) was found between the common logarithm of the proportion of gray squirrels in the harvest and the amount of hardwood sawtimber in each county.

On the basis of these limited analyses, we find that forests occupied by gray squirrels tend to be extensive and ungrazed and to contain a predominance of trees of the sawtimber size. Bakken (1952) also found a highly significant correlation between the gray:fox ratio in the squirrel harvest and the percentage of woodland for counties in central and southern Wisconsin.

Discriminant function analyses (Rao 1970) were used to determine whether significant differences exist between characteristics of forests where gray squirrels are present and where they are absent. The sampling intensity is shown in Table 1, and the 54 independent variables used in our analyses are given in Table 10. Discriminant function analysis is a linear combination of variables that emphasize the differences among groups. We used a stepwise discriminant function program with the F-levels to enter and exit set at $P \leq 0.05$ and $P \geq 0.10$, respectively.

The first discriminant function analysis treated all 54 variables and selected 7 variables as being important in separating the gray-squirrels-present from the gray-squirrels-absent groups of forests (Table 11). In a classification performance using this first discriminant function, all 24 forests where gray squirrels are absent and all 20 forests where gray squirrels are present were correctly grouped (Fig. 18)

The importance of each variable to the discriminant function can be examined by two different methods. The first method used was the magnitude of the standardized (scaled) discriminant function coefficients (Tatsuoka 1971). Examination of these values in Table 11 reveals that the amount of forests in the 23.31 km^2 (9 square miles), including the sample section, was by far the most important factor associated with the presence or absence of gray squirrels. The number of forested tracts in the 23.31 km^2, including the sample section, and the Importance Value Index (IVI) for sugar maple were the next two most important variables separating the gray-squirrels-absent and gray-squirrels-present groups (Table 11).

The second method used for examining the importance of variables to the discriminant function was the absolute value of the correlation of a given variable with the discriminant function. Shugart & Patten (1972) feel that this method, which supplies the maximum separation among groups, indicates how well the variable separates the groups.

Examination of the correlation between each of the seven variables that entered the discriminant func-

TABLE 10.—Variables used to compare forests with and without gray squirrels. Trees (diameter > 12.5 cm at height of 1 m) were tallied on 8- × 40-m transects. Shrubs, vines, and small trees (diameter 2.5–12.5 cm at height of 1 m) were tallied on 4- × 20-m transects. Foliage height diversity, percentage of vegetative cover, and number of plant species were calculated at height intervals of 0–1.5 m, 1.5–9.0 m, and > 9.0 m at every 5 m along each 8- × 40-m transect.

	Variable
1.	Density of total trees per hectare
2.	Density of total shrubs, vines, and small trees per hectare
3.	Average number of tree species per transect
4.	Average number of shrub, vine, and small-tree species per transect
5.	Average dbh of dominant and codominant trees
6.	Average dbh of trees (diameter > 12.5 cm at height of 1 m)
7.	Average height of trees (diameter > 12.5 cm at height of 1 m)
8.	Average height of shrubs, vines, and small trees
9.	Density of tree cavities per hectare
10.	Foliage height diversity
11.	Percentage of total vegetation (sum of percentage of cover in each of three layers of vegetation)
12.	Mean number of plant species below 1.5 m from ground
13.	Mean number of plant species between 1.5 m and 9 m from ground
14.	Mean number of plant species above 9 m from ground
15.	Number of timber stands in 23.31 km^2, including sample section
16.	Average size of timber stands in 23.31 km^2, including sample section
17.	Total amount of forest in 23.31 km^2, including sample section
18.	IVI[a] for shagbark hickory
19.	IVI for hickory (mockernut, bitternut, pignut)
20.	IVI for black oak
21.	IVI for blackjack oak
22.	IVI for northern red oak
23.	IVI for shingle oak
24.	IVI for pin oak
25.	IVI for white oak
26.	IVI for chinquapin oak
27.	IVI for post oak
28.	IVI for bur oak
29.	IVI for black walnut
30.	IVI for butternut
31.	IVI for pecan
32.	IVI for sugar maple
33.	IVI for silver maple
34.	IVI for box elder
35.	IVI for cottonwood
36.	IVI for bigtooth aspen
37.	IVI for honey locust
38.	IVI for black locust
39.	IVI for elms
40.	IVI for basswood
41.	IVI for hackberry
42.	IVI for hawthorns
43.	IVI for osage orange
44.	IVI for ashes
45.	IVI for black cherry
46.	IVI for crab apple
47.	IVI for willows
48.	IVI for tulip tree
49.	IVI for sassafras
50.	IVI for sycamore
51.	IVI for river birch
52.	IVI for Ohio buckeye
53.	IVI for persimmon
54.	IVI for American beech

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[a] Importance Value Index = (sum of relative frequency, relative density, and relative basal area) × $^{100}/_{3}$.

TABLE 11.—The F-levels to enter the discriminant function, the standardized discriminant function coefficients, the correlation with the discriminant function, and the mean values of the variables selected in the discriminant function analysis for forests where gray squirrels are present or absent. The discriminant function was highly significant ($X^2 = 95.5$, 7 df; $P < 0.005$).

Variable	F-level to Enter Discriminant Function	Standardized Discriminant Function Coefficients	Correlation with the Discriminant Function	Mean Values Where Gray Squirrels Are Present	Mean Values Where Gray Squirrels Are Absent
Amount of forest in 23.31 km², including and surrounding the sample section	97.53	0.708	−0.87[a]	776.3 ha	167.4 ha
Number of individual forest tracts in 23.31 km², including and surrounding the sample section	4.34	0.462	−0.42	58.2	34.8
IVI[b] for sugar maple	7.35	0.349	−0.43	6.39%	0.49%
IVI for box elder	5.44	0.191	+0.21	1.36%	4.74%
IVI for basswood	3.70	−0.129	−0.10	1.84%	1.22%
IVI for black oak	6.06	0.128	−0.43	14.72%	3.53%
Average number of plant species occurring below 1.5 m from ground	6.59	0.081	−0.45	1.24	1.13

[a] $P < 0.01$, 6 df. [b] Importance Value Index.

tion at the 95 percent level and the discriminant function revealed that only the amount of forest in the 23.31 km² (9 square miles), including the sample section, was significantly correlated ($r = 0.87$, $P < 0.01$, 6 df) with the discriminant function (Table 11). Although all seven variables were selected at the 5 percent significance level, the amount of forest apparently accounted for most of the variance associated with the presence or absence of gray squirrels.

Four other variables had nonsignificant absolute correlation values with the discriminant function. These variables were the average number of species occurring below 1.5 m from the ground ($r = 0.45$), the number of forests in the 23.31 km² including the sampled woods ($r = 0.42$), and the IVI for sugar maple and for black oak ($r = 0.43$) (Table 11).

A second discriminant function analysis considered only the IVI for the 37 principal tree species encountered on the study plots (see Table 10 for principal tree species). This analysis selected IVI values for nine species as significant variables (Table 12). In a classification performance, this discriminant function correctly classified 22 of the 24 sampled forests where gray squirrels are absent and 19 of 20 forests where they are present (Fig. 18). However, none of the correlation coefficients between the nine IVI values and the discriminant functions was significant ($P >$ 0.05, 8 df) (Table 12).

Finally, we considered only the physical characteristics of the forest environment (a compilation of tree and shrub measurements from direct counts of tree and shrub species), using discriminant function analysis to evaluate the first 14 variables listed in Table 10. The discriminant function selected five variables as most important in separating forests occupied by gray squirrels from forests where gray squirrels are absent (Table 13). A classification performance of this discriminant function correctly classified 21 of

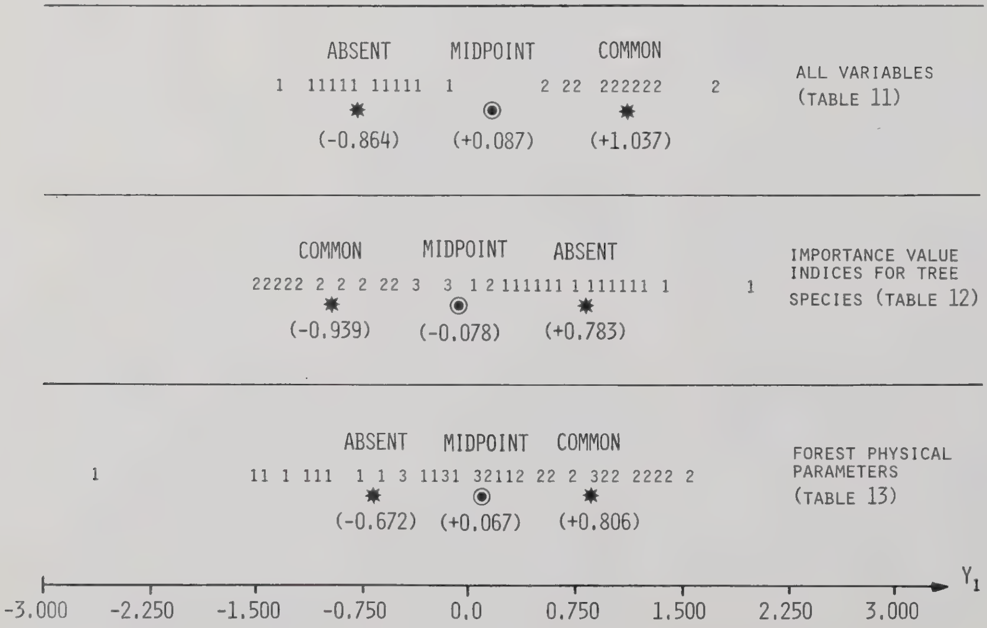

Fig. 18.—Plots of the discriminant function scores, group means (*), and midpoint scores (⊙) generated from the variables listed in Tables 11, 12 and 13. The numbers 1 and 2 denote, respectively, the location of the discriminant score for each sample forest in group 1 (gray squirrels absent) and group 2 (gray squirrels present). The number 3 denotes overlapping discriminant scores for some sample forests in group 1 and group 2.

TABLE 12.—The F-levels to enter the discriminant function, the standardized discriminant function coefficients, the correlation with the discriminant function, and the mean values of the Importance Value Index of the tree species selected in the discriminant function analysis from tree species tallied in forests where gray squirrels are present or absent. The discriminant function was highly significant ($X^2 = 52.30$, 9 df; $P < 0.005$).

Variable	F-level to Enter Discriminant Function	Standardized Discriminant Function Coefficients	Correlation with the Discriminant Function	Mean Values Where Gray Squirrels Are Present (Percent)	Mean Values Where Gray Squirrels Are Absent (Percent)
IVI[a] for elms	3.03	−0.337	+0.47	14.36	6.99
IVI for shagbark hickory	8.79	0.332	−0.11	5.26	6.94
IVI for hawthorns	16.06	0.314	−0.61	0.00	5.18
IVI for hackberry	5.41	0.301	−0.41	0.75	5.37
IVI for black oak	3.60	−0.251	+0.48	14.72	3.53
IVI for osage orange	5.29	0.241	−0.51	0.36	15.21
IVI for black cherry	5.05	0.228	−0.13	2.48	3.66
IVI for sugar maple	3.57	−0.216	+0.48	6.39	0.49
IVI for white oak	9.35	−0.200	+0.59	10.85	1.95

[a] Importance Value Index.

24 forests in the gray-squirrels-absent group and 17 of 20 forests in the gray-squirrels-present group (Fig. 18). Only the percentage of total vegetative cover (total volume of vegetation taken as the sum of the percentage of vegetative cover for the layers of vegetation from 0 to 1.5 m, 1.5 to 9 m, and >9 m) was significantly ($P < 0.05$) different between the two groups of forests, but the difference between the two groups in the number of tree cavities per hectare approached significance ($0.10 < P < 0.20$) (Table 13).

To summarize from our analysis, landscapes in central and northern Illinois that are occupied by gray squirrels have at least 20 percent of the land area covered by forest. Our sample townships ($N = 11$) where gray squirrels are present averaged 34.0 percent forested (range = 19.4–51.9 percent). The mean percentage of forest cover averaged only 3.9 (range = 0.03–18.5 percent) for townships ($N = 10$) where gray squirrels are absent.

Where gray squirrels are present, sugar maple, white oak, elms, and black oak occur in the tree strata. Sugar maple and black and white oaks are found on well-drained soils, but only the elms, which are more tolerant of water, are found in both upland and bottomland forests in Illinois. Sugar maples in Illinois are usually found on forested slopes and in upland ravines that offer a well-drained soil and a cool, moist microclimate (Braun 1950). Sugar maple is usually considered a climax species, at least on sites favoring its growth (Godman 1957). Black and white oaks are found in a wide range of sites in Illinois, but on average sites (for tree growth) these two species are usually dominant (Braun 1950). White oak is a climax species on many sites (Minckler 1957), whereas black oak may be a subclimax species due to its relatively short life-span (Brinkman 1957). The elms are not considered climax species on upland sites, where they are usually succeeded by sugar maple and American beech. American elm, however, can be considered a climax species on bottomland sites over most of its range (Guilkey 1957). Thus, all four of these species important to gray squirrels may be considered climax or near-climax species in Illinois forests.

In contrast, those species characteristic of forests where gray squirrels are absent are successional trees, usually intolerant of shade and requiring a major disturbance of the forest to become established (Table 12). Hawthorn, box elder, osage orange, black cherry, and hackberry are species that cannot withstand shade and die when overtaken by more shade-tolerant spe-

TABLE 13.—The F-levels to enter the discriminant function, the standardized discriminant function coefficients, the correlation with the discriminant function, and the mean values of the variables selected in the discriminant function analysis from the physical parameters measured in forests where gray squirrels are present or absent. The discriminant function was significant ($X^2 = 31.92$, 5 df; $P < 0.005$).

Variable	F-level to Enter Discriminant Function	Standardized Discriminant Function Coefficients	Correlation with the Discriminant Function	Mean Values Where Gray Squirrels Are Present	Mean Values Where Gray Squirrels Are Absent
Percentage of total vegetative cover	28.50	0.726	0.85[a]	221.4	181.2
Tree cavities per hectare	3.02	0.414	0.63	23.3	11.5
Average number of tree species per plot	2.75	−0.269	−0.13	1.03	1.14
Density of total trees (> 12.5 cm at height of 1 m) per hectare	3.44	−0.227	−0.40	319.1	400.8
Density of total shrubs, vines, small trees (<12.5 cm at height of 1 m) per hectare	2.71	−0.301	0.02	1,637.1	1,612.3

[a] $P < 0.05$, 4 df.

cies. The higher frequency of shagbark hickory in forests where gray squirrels are absent (Table 12) is usually the result of extensive pasturing. Hickories are relatively unpalatable to livestock and tend to resprout readily when damaged. Many shagbark hickories present today grow in long-abandoned pastures (B. Roach, U.S. Forest Service, personal communication, 1974) and often remain uncut because loggers find them unsuitable for timber products.

Forests inhabited by gray squirrels have a well-developed forest understory both above and below 1.5 m from ground level. The mean percentage of woody vegetative cover below 1.5 m was 34.2 in forests ($N = 24$) where gray squirrels are absent and 52.9 in forests ($N = 20$) where they are present. For the middle layers of woody vegetation (1.5–9 m high), the percentage values were nearly equal (83.9 where gray squirrels are absent, 90.4 where they are present). For the tree canopy, the percentage of vegetative cover was also higher for forests occupied by gray squirrels (78.1) than for forests without gray squirrels (63.1).

Taylor (1974: 282) found that the percentage of understory was significantly higher in forests where only gray squirrels lived than it was in forests where they coexisted with fox squirrels. Most descriptions of forests occupied by gray squirrels mention a dense understory and a tree canopy sufficiently developed so that gray squirrels can travel from tree to tree (Madson 1964: 10; Goodrum 1961: 9). Our data confirm that gray squirrels in Illinois thrive best in forests with closed canopies and well-developed understory structures.

Woodlands that support gray squirrels contain more tree cavities suitable for nurseries or for escaping predators and inclement weather than do forests where gray squirrels are absent. The mean number of tree cavities per hectare was twice as high in forests occupied by gray squirrels as it was in forests where they are absent (Table 13). Forests occupied by gray squirrels never averaged less than six cavities per hectare, whereas several forests unoccupied by gray squirrels had no tree cavities. Gray squirrels seem to have greater need of tree cavities for nesting and protection than have fox squirrels (Bakken 1952; Madson 1964). Packard (1956) found that gray squirrels in Kansas were restricted to forests containing tree cavities. The continued existence of fox squirrels in hedgerows and young forests (<40 years) in Illinois indicates that fox squirrels can live in forests with few tree cavities (Nixon, unpublished data).

DISCUSSION

The flora and fauna present in Illinois when the first white settlers moved north and westward across the Ohio River have undergone drastic changes during the past 175 years. The transformation of Illinois from a forest and prairie wilderness to a modern technological society has destroyed most of the plant and animal communities that had existed at least 10,000–12,000 years since the recession of the Wisconsinan glacier. The prairies were drained and plowed for production of corn, soybeans, and other crops. The forests, which once totaled 15 million acres, have been reduced by nearly 75 percent to an estimated 3.7 million acres (Essex & Gansner 1965).

Although it is useless to regret what has been lost, we cannot help marveling at descriptions of the magnificence of the virgin forests. The largest hardwoods on this continent, as described by Ridgway (1872: 661), grew in the Wabash valley:

> "Of the ninety to a hundred species of trees of the lower Wabash Valley, about seventy exceed the height of forty feet; forty-six (perhaps fifty) exceed seventy feet in height, and about thirty are known to reach or exceed the height of one hundred feet. Of the latter class, as many as nine are known certainly to reach, or even exceed, the altitude of one hundred and fifty feet, while four of them (sycamore, tulip-poplar, pecan and sweet gum), attain, or go beyond, an elevation of one hundred and seventy-five feet! The maximum elevation of the tallest sycamore and tulip trees is probably not less than two hundred feet.
>
> "Going into these primitive woods, we find symmetrical, solid trunks of six feet and upwards in diameter, and fifty feet, or more, long to be not uncommon, in half a dozen or more species; while now and then we happen on one of those old sycamores, for which the rich alluvial bottoms of the western rivers are so famous, with a trunk thirty or even forty, possibly fifty or sixty, feet in circumference, while perhaps a hundred feet overhead stretch out its great white arms, each as large as the biggest trunks themselves of most eastern forests, and whose massive head is one of those which lifts itself so high above the surrounding tree-tops. The tall, shaft-like trunks of pecans, sweet gums or ashes, occasionally break on the sight through the dense undergrowth, or stand clear and upright in unobstructed view in the rich wet woods, and rise straight as an arrow for eighty or ninety, perhaps over a hundred, feet before the first branches are thrown out."

In such forests gray squirrels reached densities that can only be guessed at today. Shelford's (1963) estimate of 1,000–2,000 squirrels per square mile certainly appears conservative, because squirrel densities today approach this level, at least on small woodlands in Illinois (Nixon & Havera, unpublished data). Gray squirrel densities seem to fluctuate in response to the amount of storable tree seed (Nixon et al. 1975;

Barkalow et al. 1970). Zawacki & Hausfater (1969) estimated that presettlement, mixed upland hardwood stands produced between 38,000 and 148,000 bushels of storable tree seed (hickories, walnuts, and acorns) per square mile. In contrast, the average yield in a mixed upland second-growth forest in southeast Ohio was only about 1,700 bushels of sound seed per square mile (10 years' data extrapolated from Nixon et al. 1975). Even if the estimate of storable tree seed produced in virgin forests was in error by a factor of 10, we would expect presettlement densities of gray squirrels to far exceed present densities.

Seton (1953: 24) estimated that there were at least 1 billion gray squirrels in their entire range in 1800. By 1900, naturalists urged that gray-squirrel hunting be banned in the northeastern United States for fear that gray squirrels would be extirpated from the region (Jackson 1961). As the virgin forests were removed or drastically modified, fox squirrels began to expand their range north and eastward from their prehistoric range, which had centered in the Mississippi Valley (Michigan, Allen 1943: 3; Indiana, Allen 1954: 9; Ohio, Baumgartner 1940: 28).

Favored habitats for gray squirrels have been described as heavy stands of timber with abundant ground cover and brush (Parmalee 1969: 139), dense timber with mature nut-bearing trees (Packard 1956: 17), and big forests of mature hardwoods and abundant understories of smaller trees and shrubs (Madson 1964: 10). In the Mississippi and Ohio river drainages both fox and gray squirrels are found primarily in habitats dominated by oaks. The numerical dominance of one or the other squirrel species apparently varies with the density of stand, tract size, and past land-use practices (Bakken 1952). In the southeastern states, however, there is an ecological separation of the two species; fox squirrels inhabit the upland pines and mixed pine-hardwoods, whereas gray squirrels live in the bottomland hardwoods (Bakken 1952; Goodrum 1961).

We conclude that at least 20 percent of the land area must be forested for gray squirrels to remain abundant. Such forests should approach maturity and contain climax species as the dominant trees, notably black oak and white oak on upper slopes and ridges or a combination of black and white oaks with basswood and sugar maple on more mesic lower slopes and ravines. Understories should be well developed, and the values for total vegetative cover in all strata should be above 200 percent (see METHODS for the derivation of vegetative cover). There should be at least six tree cavities per hectare (2.4 per acre)—no forests where gray squirrels were present had fewer. Extensive timber cutting, heavy and continuous pasturing, and repeated burning should be avoided in forests occupied by gray squirrels. These activities, which reduce tree and understory densities and the number of tree cavities and increase the number of successional tree species, generally provide fox squirrels with a competitive advantage over gray squirrels. Today, fox squirrels are present in virtually all the forests in Illinois.

Except in a few small forest reserves, it is doubtful that the optimum habitat requirements for gray squirrels will persist in central and northern Illinois forests in future years. However, if forests are allowed to mature and if that land area unsuited to agriculture (about 4 million acres in 1948, King & Winters 1952) is allowed to succeed to forest, gray squirrel numbers could stabilize and even increase in many areas. For example, there were few gray squirrels on the Kellogg Bird Sanctuary in Michigan where Allen (1943) conducted his fox squirrel studies in the 1930's. Today, gray squirrels outnumber fox squirrels on this sanctuary because the forests have matured and developed a dense understory during the intervening years (Johnson 1973).

THE FUTURE

The human population of Illinois will probably increase to nearly 14.5 million by the year 1990 (U.S. Department of Commerce 1974). We expect gray squirrels to continue to decline in the upper Mississippi, Rock River, upper Illinois, Sangamon, Vermilion, and Iroquois drainage basins because of land changes imposed by the demands of an ever-increasing human society. Gray squirrels are most vulnerable to extinction in the watersheds where they are already scarce (see Fig. 4–6, 9, 16, 17). The expected continuation of forest destruction will no doubt extirpate the gray squirrel from many of these areas.

Gray squirrels will continue to decline in the upper reaches of the Kaskaskia, Little Wabash, and Embarras basins if stream channelization and conversion of forests to cropland continue at present levels. Gray squirrels should be relatively secure in the lower portions of these basins as well as in the Big Muddy basin, the Shawnee Hills Region, and portions of the Saline River basin. However, as water impoundments are created, additional acres are strip-mined for coal, and towns and cities expand, gray squirrels will become locally scarce or absent even in these extensively forested basins.

There is a need for greater public ownership of forests in central and northern Illinois. North of the line extending between Kankakee and the Quad Cities, only about 12,800 acres of hardwood forest over 100 years old remain today (Essex & Gansner 1965 as modified by Graber & Graber 1976: 6). Of these 12,800 acres, only 1,300 are bottomland forest, a type that formerly occupied all the major floodplains in the state (Graber & Graber 1976: 6). The Illinois Division of Waterways (1969) has recommended public purchase of additional bottomlands along the Illinois River from Bureau County south to Morgan County for recreational use. Most of this range is occupied by gray squirrels.

The forests now in public ownership in central and northern Illinois should be managed (or left alone) to perpetuate a closed-canopy mature forest with a well-developed understory. Selective timber cutting should be designed to ensure that a plentiful supply of storable tree seed (mostly acorns and hickory nuts) remains after logging. Because tree seeds are important to many species of wildlife, we cannot justify the cutting of hickories and oaks on public lands in northern Illinois. Such forests, if left undisturbed, will become increasingly valuable to wildlife as private forests are removed. The U.S. Forest Service in the Shawnee National Forest has recognized the value of retaining old-growth hardwoods (85 or more years) for their aesthetic value, for wildlife and water management, and as laboratories for the study of undisturbed forest ecosystems. The Forest Service has proposed reserving 10 percent of each compartment of 400 acres or more in the Shawnee National Forest as old-growth uncut forest (Winter 1976). We believe that a much larger percentage of the forests remaining in northern Illinois should be similarly set aside.

A reintroduction of gray squirrels may become feasible in a few mature forests where they have been extirpated. We recommend that these potential release sites be sampled, using procedures similar to ours to determine the suitability of tree and shrub species, the percentage of vegetative cover, and the number of tree cavities present, before any restocking is undertaken. If the forest stands have the characteristics that we found to be associated with gray squirrel occupancy (see DISCUSSION) and if they cover at least 20 percent of the surrounding land area (minimum, 2–4 sections), a reintroduction may be successful.

The problems inherent in motivating an unresponsive public to the advantages of protecting the remaining private forests in Illinois have perplexed nearly all concerned individuals during this century. The condition of most of the present private forests indicates that the existing programs have been almost total failures. Most private forests have timber of such poor quality that there is little incentive for their continued protection. It is easier to destroy the forest or to pasture it than to wait the 50 or more years that are required to produce a harvestable timber crop.

As a first step, there must be a change in the tax laws to provide an economic incentive to retain existing forests. Methods for developing markets for such forest products as medicinal herbs, edible nuts, and wild flowers should be explored. Fees for hunting rights and access fees for fishermen, bird watchers, and hikers could also help defray the costs of preserving forest land. As one example, a landowner in Shirland Township, Winnebago County, collects approximately $400 per year for the hunting rights on his farm.

The decline of the gray squirrel, although not as dramatic as the disappearance of the timber wolf, the black bear, and the passenger pigeon, is nonetheless indicative of what has happened to the magnificent landscape of forests, prairies, and marshes that our forefathers wrested from the Indians. Unless Illinois develops a rational land-use policy that recognizes the ecological necessity of preserving and protecting as much of the remaining native landscape as possible, additional species will be extirpated and the quality of life that we presently enjoy must inevitably decline. It is abundantly clear that modern man must have wild sanctuaries where he can escape the pressures of his hectic existence. It is also clear that the continued destruction of our native ecosystems, before we truly know the consequences of such despoliation, is great folly.

LITERATURE CITED

ALLEN, D. L. 1943. Michigan fox squirrel management. Michigan Department of Conservation, Game Division Publication 100. Lansing. 404 p.

ALLEN, J. M. 1954. Gray and fox squirrel management in Indiana. 2nd ed. Indiana Department of Conservation Pittman-Robertson Bulletin 1. 112 p.

ANDERSON, R. C. 1970. Prairies in the prairie state. Illinois State Academy of Science Transactions 63 (2) :214–221.

ANGLE, P. M. 1968. Prairie state. Impressions of Illinois, 1673–1967, by travelers and other observers. University of Chicago Press. 624 p.

BAILEY, J. W. 1946. The mammals of Virginia. Williams Printing Co., Richmond, Virginia. 416 p.

BAKKEN, A. 1952. Interrelationships of *Sciurus carolinensis* (Gmelin) and *Sciurus niger* (Linnaeus) in mixed populations. Ph.D. Thesis. University of Wisconsin, Madison. 188 p. + appendixes.

BALDWIN, E. 1877. History of La Salle County Illinois. Rand, McNally & Co., Chicago. 552 p.

BARKALOW, F. S., JR., and M. SHORTEN. 1973. The world of the gray squirrel. J. B. Lippincott Co., Philadelphia. 160 p.

———, R. B. HAMILTON, and R. F. SOOTS, JR. 1970. The vital statistics of an unexploited gray squirrel population. Journal of Wildlife Management 34 (3) :489–500.

BARKER, B., J. B. CARLISLE, and R. NYBERG. 1967*a*. Little Wabash River basin study. Illinois Division of Waterways, Springfield. 78 p.

———, ———, and ———. 1967*b*. Vermilion River basin study. Illinois Division of Waterways, Springfield. 99 p.

———, ———, and ———. 1967*c*. Kankakee River basin study. Illinois Division of Waterways, Springfield. 77 p.

BATEMAN, N., P. SELBY, and A. MCLEAN, eds. 1907. Historical encyclopedia of Illinois and history of McDonough County. Vol. 2, Part 1. Munsell Publishing Company, Chicago. 825 p.

———, ———, H. G. KAUFFMAN, and R. H. KAUFFMAN, eds. 1909. Historical encyclopedia of Illinois and history of Ogle County. Vol 2. Munsell Publishing Company, Chicago.

BAUMGARTNER, L. L. 1940. The fox squirrel: its life history, habits and management. Ph.D. Thesis. The Ohio State University, Columbus. 257 p.

BELL, D. T., and F. L. JOHNSON. 1974. Flood-caused tree mortality around Illinois reservoirs. Illinois State Academy of Science Transactions 67 (1) :28–37.

BIG MUDDY RIVER BASIN COORDINATING COMMITTEE. 1971. Big

Muddy River comprehensive basin study. Vol. I. 116 p. + summary report. n. p.

Black, D. D. 1963. A review of the North American Tertiary Sciuridae. Harvard University, Museum of Comparative Zoology Bulletin 130 (3) :109–248.

———. 1972. Holarctic evolution and dispersal of squirrels (Rodentia: Sciuridae). Pages 308–322 *in* T. Dobzhansky, M. K. Hecht, and W. C. Steere, eds., Evolutionary biology. Vol. 6. Appleton-Century-Crofts, New York. 445 p.

Braun, E. L. 1950. Deciduous forests of eastern North America. The Blakiston Co., Philadelphia. 596 p.

Brinkman, K. A. 1957. Silvical characteristics of black oak. U.S. Department of Agriculture Forest Service, Central States Forest Experiment Station Miscellaneous Release 19. Columbus. 14 p.

Brown, J., and C. Cleland. 1968. The late glacial and early postglacial faunal resources in midwestern biomes newly opened to human habitation. Pages 114–122 *in* R. E. Bergstrom, ed., The Quaternary of Illinois. University of Illinois College of Agriculture Special Publication 14. Urbana. 179 p.

Brown, L. G., and L. E. Yeager. 1945. Fox squirrels and gray squirrels in Illinois. Illinois Natural History Survey Bulletin 23 (5) :449–536.

Chesemore, D. L. 1975. Ecology of fox and gray squirrels *(Sciurus niger* and *Sciurus carolinensis)* in Oklahoma. Ph.D. Thesis. Oklahoma State University, Stillwater. 348 p.

Crites, R. W., and J. E. Ebinger. 1969. Vegetation survey of floodplain forest in east-central Illinois. Illinois State Academy of Science Transactions 62 (3) :316–330.

Ellsworth, S. 1880. Records of the olden time; or fifty years on the prairies. Home Journal of Steam Printing Establishment, Lacon, Illinois. 772 p.

Essex, B. L., and D. A. Gansner. 1965. Illinois' timber resource. U.S. Department of Agriculture Forest Service, Lake States Forest Experiment Station Resource Bulletin LS-3. St. Paul, Minnesota. 56 p.

Fehrenbacher, J. B., B. W. Ray, and J. D. Alexander. 1968. Illinois soils and factors in their development. Pages 165–175. *in* R. E. Bergstrom, ed., The Quaternary of Illinois. University of Illinois College of Agriculture Special Publication 14. 179 p.

Geis, J. W., and W. R. Boggess. 1968. The Prairie Peninsula: its origin and significance in the vegetational history of central Illinois. Pages 89–95 *in* R. E. Bergstrom, ed., The Quaternary of Illinois. University of Illinois College of Agriculture Special Publication 14. 179 p.

Godman, R. M. 1957. Silvical characteristics of sugar maple *(Acer saccharum).* U.S. Department of Agriculture Forest Service, Lake States Forest Experiment Station Paper 50. St. Paul, Minnesota. 24 p.

Goff, C. C. 1952. Flood-plain animal communities. American Midland Naturalist 47 (2) :478–486.

Goodrum, P. 1961. The gray squirrel in Texas. Texas Parks and Wildlife Department Bulletin 42. Austin. 43 p.

Graber, J. W., and R. R. Graber. 1976. Environmental evaluations using birds and their habitats. Illinois Natural History Survey Biological Notes 97. 40 p.

Guilkey, P. C. 1957. Silvical characteristics of American elm *(Ulmus americana).* U.S. Department of Agriculture Forest Service, Lake States Forest Experiment Station Paper 54. St. Paul, Minnesota. 19 p.

Hahn, W. L. 1907. Notes on mammals of the Kankakee valley. U.S. National Museum Proceedings 32:455–464.

Hallberg, G. R., H. A. Semken, and L. C. Davis. 1974. Quaternary records of *Microtus xanthognathus* (Leach), the yellow-cheeked vole, from northwestern Arkansas and southwestern Iowa. Journal of Mammalogy 55 (3) :640–645.

Hall, J. K., ed. 1916. Stark County Illinois and its people. A record of settlement, organization, progress and achievement. Vol. I. Pioneer Publishing Company, Chicago. 321 p.

Harrison, H. H. 1948. American birds in color. Wm. H. Wise & Co., Inc., New York. 486 p.

Haynes, R. J., and W. D. Klimstra. 1975. Illinois lands surface mined for coal. Southern Illinois University Cooperative Wildlife Research Laboratory. Carbondale. 201 p.

Hoffmeister, D. F., and C. O. Mohr. 1972. Fieldbook of Illinois mammals. Dover Publications, Inc., New York. 233 p. (First published in 1957.)

Hopkins, O. M. 1959. Cenozoic history of the Bering land bridge. Science 129(3362):1519–1528.

Illinois Conservation Needs Committee. 1970. Illinois conservation needs inventory. University of Illinois College of Agriculture, Cooperative Extension Service, Urbana. 192 p.

Illinois Division of Waterways. 1969. Report for recreational development. Illinois River backwater areas. Prepared in cooperation with the Department of Conservation. 89 p.

Illinois State Planning Commission. 1940. Report on the lower Illinois River basin and contiguous area draining directly into the Mississippi River. Chicago. 87 p.

Inter-state Publishing Company. 1883. History of White County, Illinois. Inter-state Publishing Co., Chicago. 972 p.

Jackson, H. H. T. 1961. Mammals of Wisconsin. University of Wisconsin Press, Madison. 504 p.

Jackson, V. W. 1940. Occurrence of gray squirrels in Manitoba. Canadian Field-Naturalist 54 (5) :75.

Johnson, W. C. 1973. Gray squirrels at the Kellogg Bird Sanctuary. Jack Pine Warbler 51 (2) :75–79.

Jones, A. B., and D. T. Bell. 1974. Vascular plants of the Sangamon River basin: annotated checklist and ecological summary. University of Illinois Agricultural Experiment Station Bulletin 746. Urbana. 77 p.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70 (4) :348–357.

———, and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. American Naturalist 105 (945) :423–435.

Kennicott, R. 1857. The quadrupeds of Illinois, injurious and beneficial to the farmer. Vol. 2. Illinois State Agricultural Society Transactions 2:615–684.

Kilburn, P. D. 1959. The forest-prairie ecotone in northeastern Illinois. American Midland Naturalist 62 (1) :206–217.

King, D. B., and R. K. Winters. 1952. Forest resources and industries of Illinois. University of Illinois Agricultural Experiment Station Bulletin 562. Urbana. 95 p.

Lopinot, A. C. 1972. Channelized streams and ditches of Illinois. Illinois Department of Conservation, Division of Fisheries Special Fisheries Report 35. Springfield. 59 p.

Madson, J. 1964. Gray and fox squirrels. Olin Mathieson Chemical Corporation, East Alton, Illinois. 112 p.

Miller, R. B., and G. D. Fuller. 1921. Forest conditions in Alexander County, Illinois. Illinois State Academy of Science Transactions 14:92–108.

Mills, H. B., W. C. Starrett, and F. C. Bellrose. 1966. Man's effect on the fish and wildlife of the Illinois River. Illinois Natural History Survey Biological Notes 57. 24 p.

Minckler, L. S. 1957. Silvical characteristics of white oak. U.S. Department of Agriculture Forest Service, Central States Forest Experiment Station Miscellaneous Release 21. Columbus. 18 p.

Mohlenbrock, R. H. 1973. Forest trees of Illinois. Illinois Department of Conservation Division of Forestry, Springfield. 178 p.

———. 1975. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale. 494 p.

Mohr, C. O. 1941. Distribution of Illinois mammals. Illinois State Academy of Science Transactions 34 (2) :229–232.

Munson, P. J., P. W. Parmalee, and R. A. Yarnell. 1971. Subsistence ecology of Scovill, a terminal middle woodland village. American Antiquity 36 (4) :410–431.

Newspaper Enterprise Association, Inc. 1975. The world almanac & book of facts for 1975. New York. 976 p.

New York World Telegram & The Sun. 1954. The world almanac & book of facts for 1954. New York. 896 p.

———. 1961. The world almanac & book of facts for 1961. New York. 896 p.

Nixon, C. M., M. W. McClain, and R. W. Donohoe. 1975. Effects of hunting and mast crops on a squirrel population. Journal of Wildlife Management 39 (1) :1–25.

Packard, R. L. 1956. The tree squirrels of Kansas: ecology and economic importance. University of Kansas Museum of Natural History Miscellaneous Publication 11. Lawrence. 67 p.

Parmalee, P. W. 1957. Vertebrate remains from the Cahokia Site, Illinois. Illinois State Academy of Science Transactions 50:235–242.

———. 1959. Animal remains from the Modoc Rock Shelter Site, Randolph County, Illinois. Appendix II, pages 61–65 *in* M. L. Fowler, ed., Summary report of Modoc Rock Shelter 1952, 1953, 1955, 1956. Illinois State Museum Report of Investigations 8. Springfield. 72 p.

———. 1962*a*. The faunal complex of the Fisher Site, Illinois. American Midland Naturalist 68 (2) :399–408.

———. 1962*b*. Additional faunal records from the Kingston Lake Site, Illinois. Illinois State Academy of Science Transactions 55 (1) :6–12.

———. 1967. A recent cave bone deposit in southwestern Illinois. National Speleological Society Bulletin 29 (4) :119–147.

———. 1968. Cave and archaeological faunal deposits as indicators of post-Pleistocene animal populations and distribution in Illinois. Pages 104–113 *in* R. E. Bergstrom, ed., The Quaternary of Illinois. University of Illinois College of Agriculture Special Publication 14. Urbana. 179 p.

———. 1969. Animal remains from the archaic Riverton, Swan Island, and Robeson Hills sites, Illinois. Appendix 1, pages 139–144 *in* H. D. Winters, The Riverton culture. A second millenium occupation in the central Wabash valley. Illinois State Museum Reports of Investigations 13. Springfield. 164 p.

———, A. A. Paloumpis, and N. Wilson. 1972. Animals utilized by woodland peoples occupying the Apple Creek Site, Illinois. Illinois State Museum Reports of Investigations 23. Springfield. 62 p.

Polson, T. E., ed. 1968. Corn, commerce, and country living: a history of Henry County, Illinois. Published by the Henry County Board of Supervisors. Desaulniers & Company, Moline, Illinois. 360 p.

Preno, W. L., and R. F. Labisky. 1971. Abundance and harvest of doves, pheasants, bobwhites, squirrels, and cottontails in Illinois, 1956–69. Illinois Department of Conservation Technical Bulletin 4. Springfield. 76 p.

Rao, C. R. 1970. Advanced statistical methods in biometric research. Hafner Publishing Co., Darien, Connecticut. 390 p. (First printed in 1952.)

Ridgway, R. 1872. Notes on the vegetation of the lower Wabash valley. 1. The forests of the bottom lands. American Naturalist 6:658–665.

Schorger, A. W. 1949. Squirrels in early Wisconsin. Wisconsin Academy of Sciences, Arts & Letters Transactions 39:195–247.

Seton, E. T. 1953. Lives of game animals. Vol. 4, Part 1. Charles T. Branford Company, Boston. 440 p.

Shelford, V. E. 1963. The ecology of North America. University of Illinois Press, Urbana. 610 p.

Shugart, N. H., Jr., and B. C. Patten. 1972. Niche quantification and the concept of niche pattern. Pages 284–326 *in* B. C. Patten, ed., Systems analysis and simulation in ecology. Vol. 2. Academic Press, New York. 592 p.

Smith, C. C., and D. Follmer. 1972. Food preferences of squirrels. Ecology 53 (1) :82–91.

Stevens, F. E. 1914. History of Lee County, Illinois. Vol. 1. S. J. Clarke Publishing Co., Chicago. 537 p.

Strode, W. S. 1887. Notes ornithological and otherwise from Spoon River region, Illinois. Oölogist 4 (2) :71–72.

Tatsuoka, M. M. 1971. Multivariate analysis: techniques for educational and psychological research. Wiley and Sons, Inc., New York. 310 p.

Taylor, G. J. 1974. Present status and habitat survey of the Delmarva fox squirrel *(Sciurus niger cinereus)* with a discussion of reasons for its decline. Southeastern Association of Game and Fish Commissioners Proceedings 27:278–289.

Telford, C. J. 1926. Third report on a forest survey of Illinois. Illinois Natural History Survey Bulletin 16 (1) :1–102.

Thomas, W. 1971. Look out for white squirrels! Holiday Inn Magazine. August:9–10.

U.S. Department of Agriculture Forest Service. 1969. Timber management plan. Shawnee working circle July 1, 1969–June 30, 1978. Region 9. U.S. Government Printing Office. 23 p. + appendixes and supplement.

U.S. Department of Commerce. 1974. Statistical abstract of the United States. Annual edition 95. Washington, D.C. 1028 p.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55 (5) :1017–1029.

Winter, F. A. 1976. [Draft copy of proposed wildlife management- plan, Shawnee National Forest.] U.S. Department of Agriculture Forest Service [Harrisburg, Illinois.] 124 p.

Winters, H. D. 1969. The Riverton culture. A second millennium occupation in the central Wabash valley. Illinois State Museum Reports of Investigations 13. Springfield. 164 p.

Wood, F. E. 1910. A study of the mammals of Champaign County. Illinois State Laboratory of Natural History Bulletin 8 (5) :501–613.

Yeager, L. E. 1949. Effect of permanent flooding in a river-bottom timber area. Illinois Natural History Survey Bulletin 25 (2) :33–65.

Zawacki, A. A., and G. Hausfater. 1969. Early vegetation of the lower Illinois valley. Illinois State Museum Reports of Investigations 17. Springfield. 67 p.

APPENDIX

Common and scientific names of plants and animals mentioned in text or tables.

Plants[a]

- Apple, crab—*Malus* spp.
- Ash
  - green—*Fraxinus pennsylvanica* var. *subintegerrima*
  - white—*F. americana*
- Aspen, bigtooth—*Populus grandidentata*
- Basswood—*Tilia americana*
- Beech, American—*Fagus grandifolia*
- Birch, river—*Betula nigra*
- Box elder—*Acer negundo*
- Buckeye, Ohio—*Aesculus glabra*
- Butternut—*Juglans cinerea*
- Cherry, black—*Prunus serotina*
- Cottonwood—*Populus deltoides*
- Elm
  - American—*Ulmus americana*
  - slippery—*U. rubra*
- Gum, sweet—*Liquidambar styraciflua*
- Hackberry—*Celtis occidentalis*
- Hawthorns—*Crataegus* spp.
- Hickory
  - big shellbark—*Carya laciniosa*
  - bitternut—*C. cordiformis*
  - mockernut—*C. tomentosa*
  - pignut—*C. ovalis, C. glabra*
  - shagbark—*C. ovata*
- Hop hornbeam—*Ostrya virginiana*
- Ironwood (blue beech)—*Carpinus caroliniana*
- Locust
  - black—*Robinia pseudoacacia*
  - honey—*Gleditsia triacanthos*
- Maple
  - red—*Acer rubrum*
  - silver—*A. saccharinum*
  - sugar—*A. saccharum*
- Oak
  - black—*Quercus velutina*
  - blackjack—*Q. marilandica*
  - bur—*Q. macrocarpa*
  - cherrybark—*Q. falcata* var. *pagodaefolia*
  - chinquapin—*Q. muhlenbergii*
  - northern red—*Q. rubra*
  - overcup—*Q. lyrata*
  - pin—*Q. palustris*
  - post—*Q. stellata*
  - shingle—*Q. imbricaria*
  - Shumard's—*Q. shumardii*
  - swamp chestnut—*Q. michauxii*
  - swamp white—*Q. bicolor*
  - white—*Q. alba*
- Osage orange—*Maclura pomifera*
- Pecan—*Carya illinoensis*
- Persimmon—*Diospyros virginiana*
- Sassafras—*Sassafras albidum*
- Shadbush—*Amelanchier arborea*
- Sugarberry—*Celtis laevigata*
- Sycamore—*Platanus occidentalis*
- Tulip tree—*Liriodendron tulipifera*
- Walnut, black—*Juglans nigra*
- Willows—*Salix* spp.

Animals[b]

- Bear, black—*Ursus americanus*
- Deer, white-tailed—*Odocoileus virginianus*
- Pigeon, passenger[c]—*Ectopistes migratorius*
- Squirrel
  - fox—*Sciurus niger*
  - gray—*S. carolinensis*
  - red, European—*S. vulgaris*
  - red—*Tamiasciurus hudsonicus*
- Vole, yellow-cheeked—*Microtus xanthognathus*
- Wolf, timber—*Canis lupus*

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[a] Source: Mohlenbrock (1973).
[b] Source: Hoffmeister & Mohr (1972).
[c] Source: Harrison (1948).

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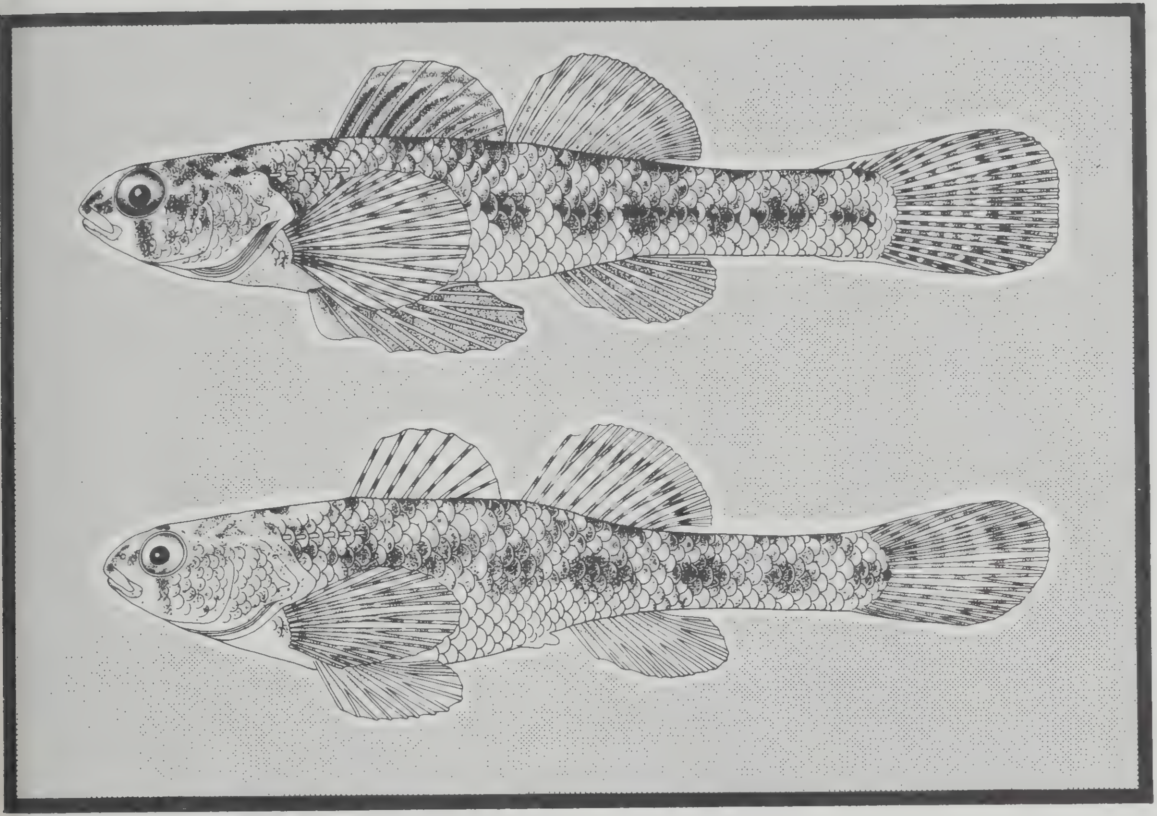

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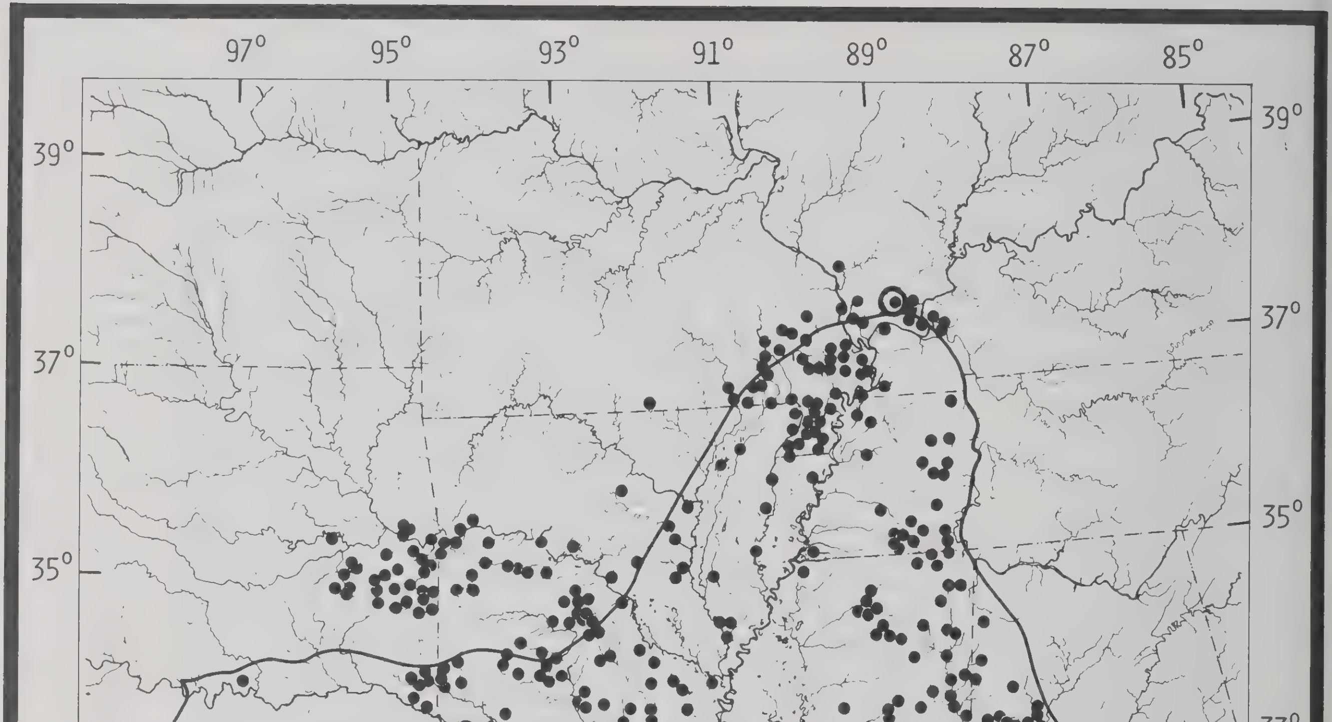

Fig. 1.—The distribution of *Etheostoma proeliare*. The solid black line represents the Coastal Plain boundary. The study area is enclosed within the circle.

THE LIFE HISTORY OF THE CYPRESS DARTER, *ETHEOSTOMA PROELIARE,* IN MAX CREEK, ILLINOIS

Brooks M. Burr and Lawrence M. Page

Of the three species *(Etheostoma proeliare, E. fonticola, E. microperca)* in the subgenus *Microperca, E. proeliare* has been the poorest known ecologically. This report provides information on the life history of *E. proeliare* at a study site on Max Creek, Johnson County, Illinois. A similar report being completed on *E. microperca* will compare information on *E. microperca* and *E. proeliare* with that recently published on *E. fonticola* (Schenck & Whiteside 1976, 1977*a*, 1977*b*).

Etheostoma proeliare was described by Hay (1881) from a specimen collected in a tributary of Tuscumbia River at Corinth, Alcorn County, Mississippi. The species ranges from southern Illinois and southeastern Missouri south to Texas and the Florida panhandle. In general the distribution of the species is limited to streams and lakes on the Coastal Plain (Fig. 1). A detailed morphological description of the species is found in Burr (1978).

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STUDY AREA

Etheostoma proeliare is distributed sporadically in southern Illinois and is common only in highly localized areas. Max Creek in Johnson County is a tributary of Bay Creek (Ohio River drainage), and at the Illinois Route 147 bridge (4 km SW Simpson) and for a short distance downstream, *E. proeliare* is one of the most common fishes found. This site (Fig. 2) was selected for the life-history study.

Max Creek transects the Shawnee Hills and the study area lies in a deep valley. The substrate at the study area is mostly hard clay with some sand and patches of small gravel. Water is seldom over 1 m deep. Several springs enter Max Creek upstream from the study area. During high water the current is moderatly fast and habitats are poorly defined. During low water clay-bottom pools and gravel-bottom riffles are formed. Filamentous algae are abundant in summer and fall in both riffles and shallow pools that are exposed to sunlight, but are absent in winter and early spring and in deep pools and shaded areas. Some rooted vegetation is present in shallow water areas. During the low water levels in late fall and winter, a layer of leaves and sticks covers the bottom of the stream. The accumulations of leaves and sticks are eventually washed away but remain, mostly along pool margins, well into the summer.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12, and is a contribution from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Brooks M. Burr, formerly a Research Assistant at the Survey, is Assistant Professor, Department of Zoology, Southern Illinois University, Carbondale. Dr. Lawrence M. Page is an Associate Taxonomist at the Survey.

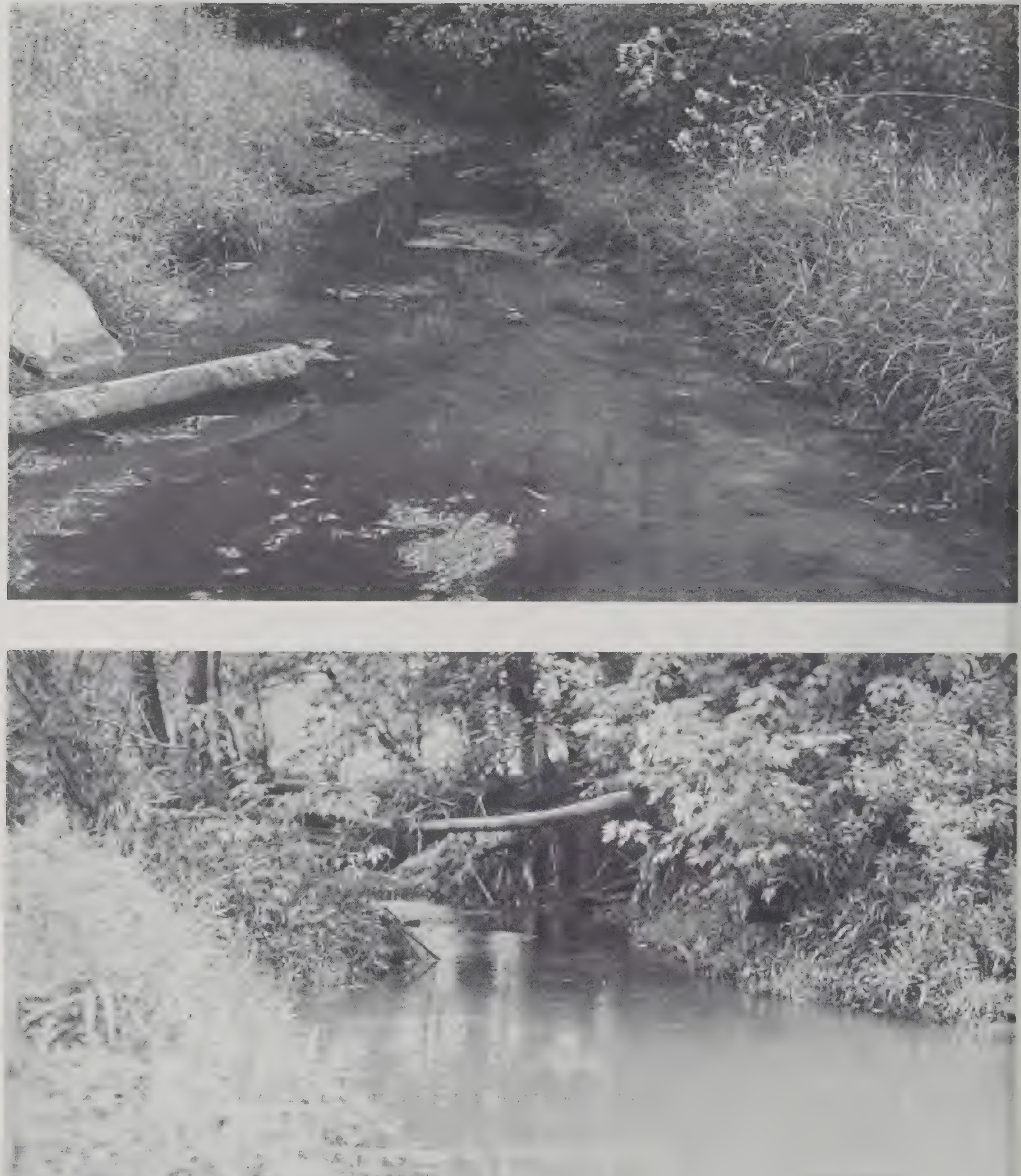

Fig. 2.—Max Creek at Illinois Route 147 bridge, 4 km SW of Simpson, Johnson County, Illinois. In the top photo, taken on 15 September 1976, the creek is low with much exposed vegetation. In the bottom photo, taken on 4 May 1977, the creek is high and roiled.

Fifty species of fishes occur in the Bay Creek system. At the study area the most common, in addition to *E. proeliare,* are *Pimephales notatus, Notropis fumeus, N. umbratilis, Cottus carolinae, Aphredoderus sayanus, Etheostoma chlorosomum, E. gracile, Fundulus olivaceus,* and *Erimyzon oblongus.* Other darters in the Bay Creek system are *Percina maculata, Etheostoma caeruleum, E. kennicotti, E. nigrum,* and *E. spectabile.*

METHODS

Methods of study were the same as those employed by Page (1974:4–5) except as noted below. Observations and minnow-seine collections were made at approximately monthly intervals from 25 October 1975 to 9 October 1976. A total of 482 specimens was preserved and stored in 10-percent formalin. Additional data on reproduction were accumulated on 4 May 1977.

Attempts were made to collect specimens by habitat, but often boundaries of habitats (e.g., pools, riffles) in Max Creek were poorly defined. When it became evident that *E. proeliare* was found whereever dead leaves, sticks, and other debris were accumulated or vegetation was growing, regardless of habitat, these attempts were discontinued.

In addition to specimens from the study area, *E. proeliare* from nearly all museum collections were examined to determine probable spawning periods in other localities and other years. Indicators of spawning preparedness were the following: maximally tuberculate males, well-developed lateral pelvic fin flaps on males, peak breeding coloration, and females swollen with mature ova (often visible through body wall). Collections of specimens were considered to be in spawning condition if all, or if only some of the specimens, were in peak reproductive condition.

HABITAT

In the study area the greatest concentrations of *E. proeliare* were in accumulations of leaves and sticks on the bottom of the stream and, secondarily, in filamentous algae. Pools, more than riffles, acted as depositories for leaves and sticks, and generally yielded more specimens of *E. proeliare* than did riffles. It was clearly the presence of leaves and/or vegetation that was important to E. *proeliare* rather than the physical attributes of pools and riffles; pools and riffles without leaves or vegetation yielded few or no *E. proeliare.* Pools and riffles with leaves or vegetation typically yielded large numbers of *E. proeliare.*

Collections of *E. proeliare* made elsewhere (in Alabama, Illinois, Kentucky, Louisiana, and Missouri) by the authors support their observation at the study area of the affinity of the species for leaves and vegetation. In some streams in which *E. proeliare* is found, the vegetation inhabited is nothing more than exposed tree roots along bank undercuts. Both streams and lakes are inhabited by *E. proeliare* and, in general, the more leaves or vegetation present, the larger the population of *E. proeliare.*

The preferred habitat of *E. proeliare* is best described as leaf-laden and/or vegetated sluggish water bodies, including small to large streams and the margins of lakes. No distinction between the habitat of young *E. proeliare* and that of adult *E. proeliare* is evident.

REPRODUCTION

Reproductive Cycle of the Male

The enlargement of the genital papilla of the male is a gradual process, occurring over many months rather than only during the immediate prespawning period. By March the papilla is proportionally much larger than those of males collected earlier in their life history (Fig 3). The testes of breeding males are greatly enlarged, white and spongy. Those of nonbreeding males are small and translucent.

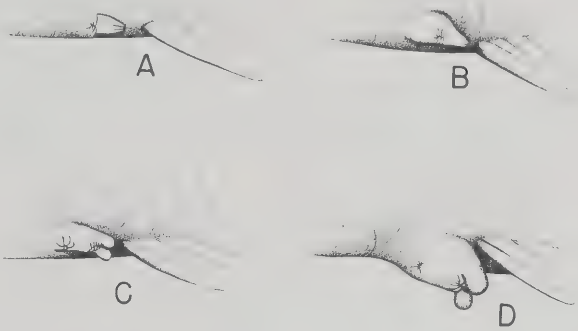

Fig. 3.—Genital papillae of *Etheostoma proeliare.* A, nonbreeding male; B, breeding male; C, nonbreeding female; D, breeding female. The breeding specimens were 1 year old, collected on 13 April 1976; the nonbreeding specimens were −1 year old, collected on 15 September 1976.

In studies of other darters it was possible to recognize a minimum length that males had to attain to become sexually mature and spawn their first year. In *E. proeliare* all spring-collected males, including the smallest, a 25.5-mm male collected in April, were sexually mature and apparently capable of spawning.

As early as late January males began to develop breeding colors and structures. The first dorsal fin of the male began to develop more black pigment in the basal one-third of the anterior membranes and the lateral flaps of skin began to form on the pelvic fins. No tubercles were present on January-collected specimens, and the anal and pelvic fins had only a few scattered melanophores.

By late February tubercles were developed sparsely on one or two anal rays and slightly better developed on the median pelvic rays of a few large males. The first dorsal fin pattern intensified, the pelvic fin flaps

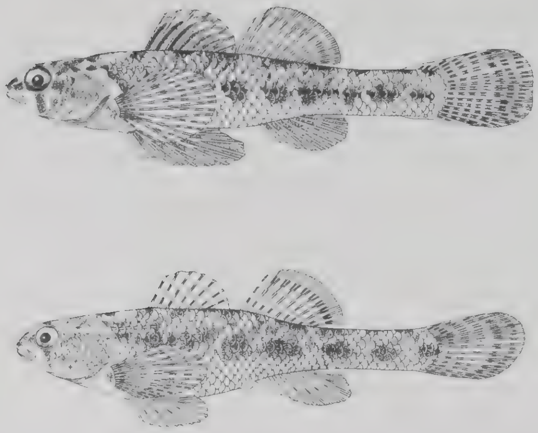

Fig. 4.—Breeding male (upper) and breeding female (lower) *Etheostoma proeliare* collected in Max Creek on 10 March 1976. The male was 33 mm; the female was 31 mm. Drawings by Alice A. Prickett.

were nearly developed to their maximum, and the anal and pelvic fins had a heavy concentration of melanophores.

From about the second week of March to the third week of June, the male breeding colors and structures were at their peak development (Fig. 4). The body was dark brown with 8–10 intense mid-lateral blotches interspersed with specks of iridescent cream-yellow. The teardrop and postorbital bar were intense black. The base of the pectoral fin and the bottom half of the opercle were iridescent cream-yellow. The flesh overlying the back of the head, second dorsal, and caudal fins was thick and milky white. The iris of the eye was bright red-orange with some iridescent green. The first dorsal fin was black on the basal one-third of the anterior membranes, more gray in the posterior membranes. Medially, the anterior membranes of the first dorsal fin had intense red-orange spots; similar spots were more subdued in the posterior membranes. The second dorsal and caudal fins had five or six amber-orange bands. The anal and pelvic fins had heavy concentrations of melanophores, mostly basally on the membranes. The pectoral fin rays were sharply outlined by melanophores.

Tubercles were developed maximally on all the pelvic fin rays and all the anal fin elements except the second spine (when present), and were concentrated most heavily on the central portions of the fin rays. The lateral pelvic fin flaps were developed maximally with the skin greatly expanded on both sides of the pelvic spine and between pelvic rays one through three.

Reproductive Cycle of the Female

The genital papilla of the female enlarged over a several-month period, and by the spawning period was a swollen bilobed structure (Fig. 3) much different from the papilla of the male.

The female color and pattern change little prior to and during the breeding period (Fig. 4). Some females developed a suffusion of orange in the anterior portion of the first dorsal fin, an orange iris of the eye, and amber second dorsal and caudal fin bands. Other fins were clear generally except that the pectoral rays were often distinctly outlined by melanophores.

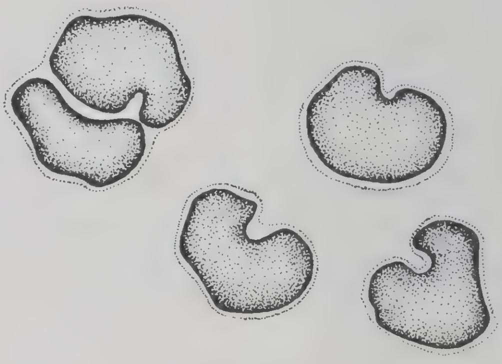

Fig. 5.—Mature eggs removed from an ovary of *Etheostoma proeliare*.

Small white ova were discernible in females collected as early as November. Somewhat larger, yellow ova appeared in females as early as January, and larger dark yellow ova were found in females collected as early as March. Prior to spawning the large dark yellow ova transformed into translucent, half-doughnut shaped eggs with one large oil droplet (Fig. 5). Eggs averaged 0.7 mm across.

All females collected in spring (March to June) had large, maturing or translucent ova and apparently would have spawned. The smallest spring-collected female was 25.8 mm and was collected on 4 May 1977.

In 17 females collected in March–June 1976 and in May 1977 the number of mature ova ranged from 26 to 116 (Table 1). For these females there was no significant correlation between the number of mature ova and the standard length, nor between the number of mature ova and the adjusted body weight; for both relationships the correlation coefficient *(r)* was less than 0.10. Significant correlations were found for these relationships in other species of darters, and the absence of correlation for the number of mature ova and size of *E. proeliare* may be because they spawn only once (at 1 year of age) and are all about the

TABLE 1.—Relationship between size, age, and ovary weight of *Etheostoma proeliare* females and the number of mature ova produced. All females were 1 year (11–14 months) old.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Month of Collection	Ovary Weight in Grams	Number of Mature (Dark Yellow or Translucent) Ova
28	0.27	March	0.06	44
29	0.29	April	0.09	98
30	0.36	April	0.09	72
30	0.39	April	0.10	116
31	0.39	April	0.08	112
32	0.44	April	0.08	26
32	0.46	April	0.09	90
29	0.26	May	0.06	56
29	0.27	May	0.06	58
30	0.37	May	0.05	78
31	0.37	May	0.07	90
31	0.38	May	0.06	110
31	0.40	May	0.09	106
33	0.44	May	0.07	76
35	0.47	May	0.09	98
36	0.51	May	0.09	92
30	0.34	June	0.02	28

[a] Adjusted body weight is the specimen's weight after removal of the ovaries, stomach, intestine, and liver.

same size at spawning. Another reason may be that *E. proeliare* disperses its eggs over a sizeable area rather than concentrates them as some other species of darters (especially species of *Catonotus*) do. Spawning is more likely to be interrupted and some of the 17 females examined may have laid a portion of their eggs prior to being captured; if so, egg counts made on them were not of the total number of eggs produced.

From September until the spawning season, ovaries increased markedly in size in relation to the body of the female (Fig. 6). For the females examined, the relationship between the mean of the weight of the ovaries divided by the adjusted body weight (Y) and the month (X), with September = 1 and April (the month of the greatest spawning activity) = 8, was log Y = 0.848 + 0.202 X, with r = 0.909 (Fig. 6). The proportionally largest ovaries (equaling 31 percent of the adjusted body weight) were found in a 29-mm female collected on 13 April 1976. In the 17 females represented in Table 1, ovary-weight-to-adjusted-body-weight ratios ranged from 0.059 to 0.310 and averaged 0.194.

Spawning

At the study area *E. proeliare* was ripe from March to June. Some individuals transferred from Max Creek to aquaria on 10 March 1976, 13 April 1976, 29 April 1976, and 4 May 1977, spawned on the following day and for a few days thereafter. The stream temperatures at the time of capture of ripe *E. proeliare* ranged from 9.5° to 16°C; aquaria temperatures ranged from 22° to 25°C. The sudden rise in temperature may have caused spawning to occur earlier among captive individuals than among those remaining in Max Creek. Spawning was not observed in Max Creek, but the spawning season there, based on tank observations and preserved individuals, is approximately from mid-March to early June. Ripe individuals were captured in shallow, sluggish water with accumulations of dead leaves, algae, or other vegetation, and this is probably the spawning habitat.

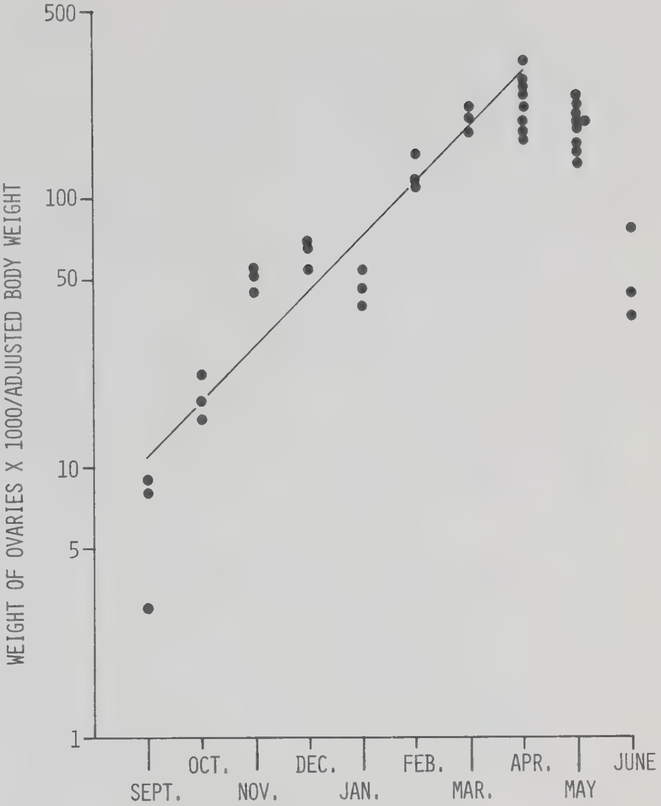

Fig. 6.—Monthly variations in ovarian weight relative to adjusted body weight of 5- to 14-month-old *Etheostoma proeliare*. The vertical axis is a logarithmic scale.

Examinations of preserved museum specimens from throughout the range of the species indicated that spawning occurs earlier in the southern portions of the range and later in northern portions (Table 2). Specimens from Lake Pontchartrain drainages are ripe from January through April. Most of the more northern populations are ripe from March to June. One collection from the upper St. Francis River, Missouri, (KU 9276) had both males and females in extreme spawning condition on 2 August. The geographic variation in spawning periods is related presumably to the warmer water temperatures on earlier dates at more southern latitudes.

Spawnings in aquaria occurred in early morning, during midday, and in the evening, and were observed many times. Courting consisted mainly of a

TABLF 2.—Frequency distribution by month of collection of breeding *Etheostoma proeliare* from throughout the range of th species. Drainages are arranged primarily by latitude and geographic propinquity where possible. Numbers in parentheses are num bers of collections supporting a reproductive condition, as explained under Methods. Museum collection abbreviations are given i the introduction.

Drainages	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Collection Dates
Lake Pontchartrain, LA (10—BU 234, 306; CU 15535; NLU 977, 1662, 4142; TU 45041, 75882, 83129; UMMZ 16117)	4	1	3	2	..	..	..	..	4 January–8 April
Mermentau-Calcasieu R., LA (2—TU 44565, 50225)		1	1	..	..	..	..	..	8 February–23 March
Trinity R., TX (2—TCWC 4025.4; TNHC 1348)			2	..	.	..	..	..	23–24 March
Red R., LA, TX, OK, AR (12—BU 213, HWR 72-11; OAM 5054, 5629, 6464; OUMZ 37979; TCWC 4064.7, 4068.8; TNHC 522; TU 93010; USNM 163116, 172985)	.	1	4	6	1	..	..	..	17 February–18 May
Ouachita R., LA, AR (19—BU 1561; HWR 72-12; INHS 75701; NLU 1414, 15185, 31205, 31277, 31368, 31480, 31671, 33188, 33302, 33360; TCWC 129.18; TMB 74-16; TU 76118, 87611; USNM 165951, 172567)		6	5	7	1	..	..	..	4 February–10 May
Big Black-Yazoo R., MS (7—FSU 10554; NLU 161110; UMMZ 144699, 161062, 161110, 161136; USNM 165959)	.	.	1	6	..	..	..	..	1 March–21 April
Upper Pearl R., MS (4—CU 37538; FSU 10643, 10676; TU 39989)		.	1	3	..	..	..	..	10 March–24 April
Tombigbee-Black Warrior R., AL (10—CU 64665; TU 40499, 76978, 77045; UAIC 915, 1296, 1865, 1892, 1898, 4507.08)		2	4	4	..	..	..	..	4 February–22 April
Arkansas R., AR (8—KU 6191, 6208, 9826; OAM 4549; TMB 74-15; TU 2224; UMMZ 177142; USNM 165891)		1	1	6	..	..	..	..	16 February–22 April
White R., AR (4—FSU 14498; TMB 72-3; TU 49830, 49970)			1	2	..	1	..	..	26 March–6 June
Hatchie R., MS, TN (2—MSU 2670, 6058)		..	.	1	1	..	..	..	8 April–6 May
Tributaries, Tennessee R., MS, TN (2—TU 87969; UT 91.1063)			1	..	1	..	..	..	1 March–8 May
St. Francis R., AR, MO (4—FMNH 60731; FSU 14342; KU 9276, 16079)		.	1	..	..	2	..	1	11 March–2 August
Tributaries, Ohio R., IL, KY (7—INHS 1358, 75840; Max Creek specimens)		.	3	2	1	1	..	.	3 March–17 June

male and female darting about the aquarium with the female leading the male close behind her. At times the male mounted the female, clasped her upper sides with his large pelvic fins, and while mounted he occasionally rubbed his chin on the top of her head and on her cheeks in a way similar to the courting behavior described for *E. gracile* (Braasch & Smith 1967: 7).

The female selected the site for egg deposition and with the male close behind her elevated to the site (Fig. 7). Eggs ranged from 0.5–1.1 mm across and were attached to dead leaves, twigs, the sides and undersides of large rocks, and the glass sides of the aquarium. When the egg site was reached, the male mounted the back of the female; the two bodies vibrated together for a few seconds and were curved in such a way that the female genital papilla was placed on the selected spot where 1–3 adhesive eggs were laid. The male body was curved such that milt could be released near the eggs. At the instant of egg laying the female always had her mouth wide open; the male's mouth was always closed. Eggs were laid as high as 13 cm above the substrate of the aquarium.

Typically, several eggs were laid at one site (e.g., underside of leaf). After 1–3 eggs were laid, the pair of darters dropped to the bottom and separated and rested for as long as a minute before they resumed spawning. Then the pair darted to a site 5–15 cm away from the first site and laid several more eggs. This sequence was repeated many times. Eggs were laid most often on dead leaves, and as many as 45 eggs were found on one leaf.

Laying eggs on leaves, undersides of rocks, etc., required that the spawning pair assume vertical and inverted positions. To maintain these positions, rapid vibrations of the caudal and pectoral fins were required. The male position on top of the female (even while inverted) was firmly maintained by the expanded male pelvic fins, which enabled him to tightly grip the middorsum of the female. The male

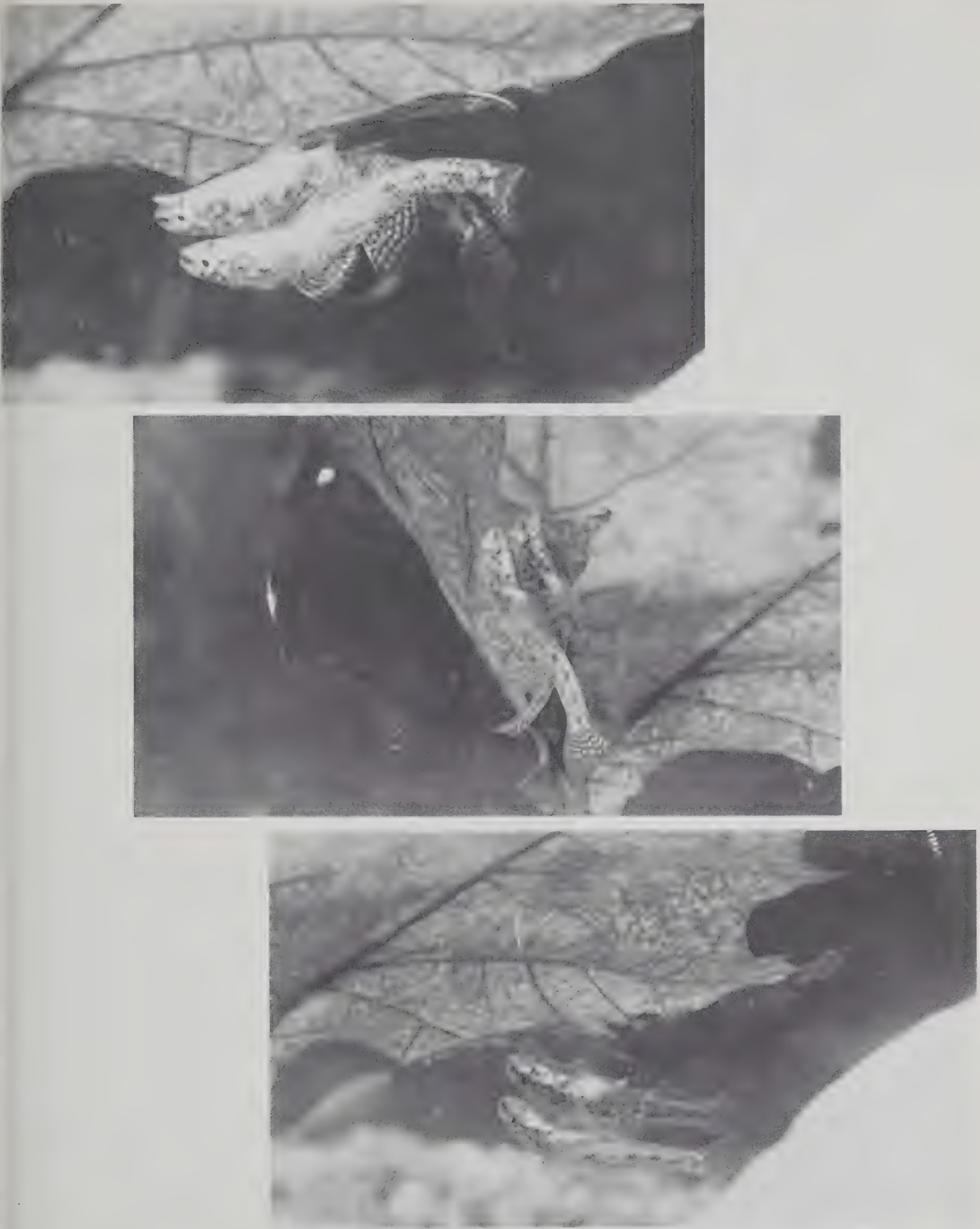

Fig. 7.–*Etheostoma proeliare* spawning in aquaria. Top: Male and female are inverted as egg and sperm are released on underside of leaf. Middle: Male and female in vertical position as egg and sperm are released on underside of leaf. Bottom: Male and female descending from egg deposition site. Note several eggs on edge of underside of leaf.

anal fin was always fully extended and pressed against the side of the female. The second dorsal fin of the female was pressed against the side of the male above his anal fin. The female first dorsal fin was retracted, but the male's dorsal fins remained fully spread. Some males which were observed spawning in aquaria on 10 March 1976 did not have the anal and pelvic fin tubercles developed. In this species the structures are not necessary for maintenance of body contact between the sexes, and are probably not used in defense; when present they may, however, aid in stimulation of the female as has been suggested for other fishes (see review by Wiley & Collette 1970: 148).

In aquaria females were not observed to spawn with more than one male, but in a natural environment, especially in a highly populated area, females may spawn with more than one male. When two males and five females were placed in an aquarium, both males successfully spawned, but the smaller male spawned more often and was observed to spawn with three different females. On several occasions the smaller male pursued and attempted to mount the larger male. Neither sex gave any attention to the eggs after spawning.

Other darters which spawn on live or dead vegetation similar to that utilized by *E. proeliare* (i.e., excluding riffle plants) are *E. microperca* (Petravicz 1936: 81–82; Winn 1958*a*: 201–202, 1958*b*: 161), *E. fonticola* (Strawn 1956: 14), *E. gracile* (Braasch & Smith 1967: 7), *E. fusiforme* (Fletcher 1957: 203; Smith 1907: 269), *E. exile* (Winn 1958*a*: 198, 1958*b*: 161), *E. edwini* (Williams 1976: 107), and ***E. chlorosomum*** (Winn 1958*b*: 189). The spawning of *E. proeliare,* in which the male clasps the back of the female with his pelvic fins and goes up into a vertical or inverted position, is most similar to that described for the closely related *E. microperca.* Detailed observations on the spawning act of the closely related *E. fonticola* have not been published, but Strawn's (1956: 14) brief description indicates a similar behavior.

Sexual Dimorphism

A taxonomic study of *E. proeliare* from throughout the range of the species revealed that 7 of 16 morphometric characters measured on breeding specimens showed highly significant ($P < 0.005$) sexual dimorphism (Burr 1978). Males have significantly longer heads; longer postdorsal lengths; deeper caudal peduncles; and longer pelvic, pectoral, anal, and second dorsal fins. Sexual dimorphism in tuberculation, pelvic fin structure, coloration, and genital papillae are discussed elsewhere in this paper.

DEVELOPMENT AND GROWTH

Eggs incubated in aquaria at 10°C (50°F) developed to near hatching but failed to hatch. Eggs incubated at 15°C (60°F) hatched in 300 ± 9 hours (12.5 days), at 20°C (67°–68°F) hatched in 211 ± 23 hours (8–10 days), and at 22°–23°C (71°–74°F) hatched in 131 ± 9 hours (5.5 days).

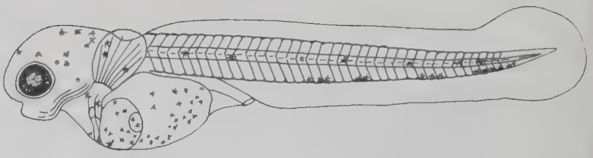

Fig. 8.—*Etheostoma proeliare* hatchling (3.7 mm in total length).

Hatchlings ranged from 3.4 to 3.7 mm in total length and were mostly translucent but had melanophores on the head, yolk sac, and some of the myomeres (Fig. 8). The pectoral fins and jaw were well developed as in other species of *Etheostoma* studied (e.g., *E. gracile*—Braasch & Smith 1967: 9; species of *Catonotus*—Page 1974: 11, 1975: 8–9; and Page & Burr 1976: 8).

On 17 June 1976 a series of 30 young *E. proeliare* ranging from 9 to 19 mm was collected in the study area. At 9 mm melanophores were loosely concentrated on top of the head, along the mid-side and at the fin bases. At 12 mm lateral blotches and dorsal saddles were discernible, and at 15 mm the color pattern of the adult had formed.

Scales were not present at 9 mm. At 12 mm squamation was nearly complete, but scales did not ap-

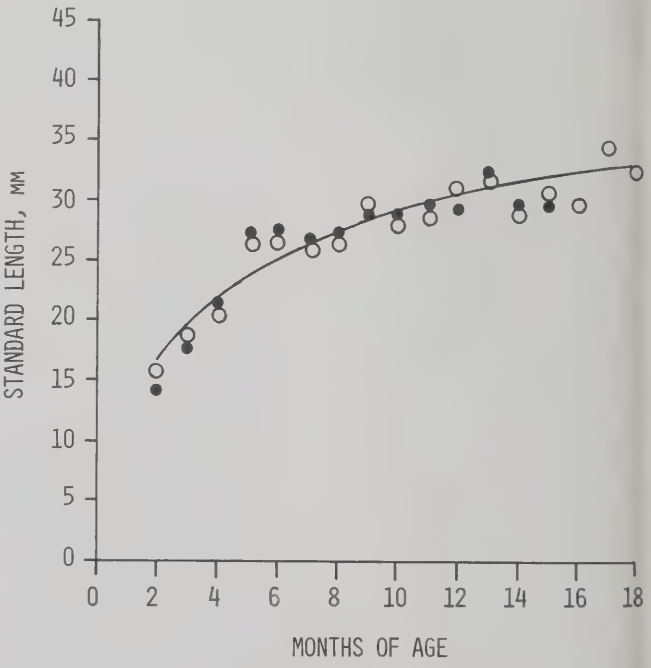

Fig. 9.—Size distribution by age of *Etheostoma proeliare* collected in Max Creek between 25 October 1975 and 9 October 1976. Black dots represent sample means for males; circles represent sample means for females. Regression line is for both sexes. A total of 482 specimens is represented.

pear on the cheeks, opercles, and prepectoral areas until considerably later (at about 20 mm on specimens collected 13 July 1976). Head canals began forming at about 12 mm and were completed between 15 and 17 mm. The lateral line began forming at about 14 mm.

Males and females grew at nearly the same decreasing rate (Fig. 9). The relationship between standard length (Y) and age in months (X) for males is $Y = 10.8 + 18.08 \log X$, with $r = 0.876$, and for females is $Y = 11.7 + 17.08 \log X$, with $r = 0.922$.

The largest specimen examined from Max Creek was a 36.4-mm male collected on 20 May 1976. The largest specimen known is a 39.6-mm female collected on 18 February 1977 from Cheniere Lake, Ouachita Parish, Louisiana.

At 1 year (12 months), males ($N = 11$) averaged 29.2 mm and females ($N = 24$) averaged 30.7 mm. *E. proeliare* reached one-half of the first year's mean growth in about 8 weeks. This is a shorter period than that recorded for other darters except *E. gracile* and *Percina phoxocephala* which were estimated to have reached one-half of the first year's mean growth in only 1 week (Braasch & Smith 1967: 9) and 2 weeks (Page & Smith 1971: 9), respectively.

DEMOGRAPHY

Density

Density samples were made by habitat on six separate dates but because habitat (e.g., pool, riffle) boundaries were defined poorly and the species occupied leaves and vegetation regardless of habitat, these data are not presented. The highest density found was 5.5 *E. proeliare*/m^2 in a vegetated, gravel area below a riffle on 21 January 1976.

Composition

Of the 482 *E. proeliare* collected in Max Creek between 25 October 1975 and 9 October 1976, 93.4 percent were up to 1 year of age and 6.6 percent were between 1 and 2 years of age (Table 3).

TABLE 3.—Distribution of sexes and year classes in samples of *Etheostoma proeliare* collected in Max Creek between 25 October 1975 and 9 October 1976.

	Number by Year Class		
Sex	−1	1+	Total
Male	222	6	228
Female	228	26	254
Total	450	32	482

There was no significant deviation from a 1 to 1 sex ratio in the first-year (−1) age class, but because of greater longevity females strongly predominated [4.3 to 1.0 ($\chi^2 = 12.5$; $P < 0.005$)] in the 1+ year class.

Survival

Of the 228 males collected 97.4 percent were up to 1 year of age and only 2.6 percent were over 1 year of age. Of the 254 females collected, 89.8 percent were up to 1 year of age and 10.2 percent were over 1 year of age. Assuming that each year class was collected in proportion to its relative number in the population, only 2.7 percent of the first-year males and 11.4 percent of the first-year females survived to a second year. For males and females combined, the survival to a second year was 7.1 percent. These survival values are much lower than ,those for other darters studied, and the short life span of *E. proeliare* is a distinctive feature among darters. The oldest *E. proeliare* from Max Creek examined (assuming an April hatching) were one 18-month-old female collected October 1975 and two 18-month-old females collected in October 1976. The oldest male from Max Creek examined was a 15-month-old specimen collected in July 1976.

Migration

E. proeliare was found with relative ease at the study area during every month of the study period and there was no indication of any migration up and down the stream or from one habitat to another.

Territoriality

No territoriality was observed in *E. proeliare,* including among males before and during the breeding season. Petravicz (1936) did not observe territorial behavior in the closely related *E. microperca,* but later studies by Winn (1958*b*) showed that the species exhibited some territoriality. Winn suggested that overcrowding aquaria with too many individuals resulted in abnormal behavior; it is possible that aquaria used in this study were overcrowded and territoriality was inhibited. Perhaps under more natural conditions *E. proeliare* uses plants in the delimitation of a territory as was found for *E. microperca* (Winn 1958*b*: 168). If *E. proeliare* does not exhibit territorial behavior, it may be a response to the fact that the eggs are scattered over a loosely defined area and not in a small concentrated area selected and guarded by the male.

DIET

The stomach contents of 118 *E. proeliare* were mostly chironomid larvae and small crustaceans (Table 4). Insects other than chironomids made only small contributions to the diet. Compared to other darters studied, e.g., *Percina sciera* (Page & Smith 1970), *P. phoxocephala* (Page & Smith 1971), *P. nigrofasciata* (Mathur 1973), *Etheostoma squamiceps* (Page 1974), *E. kennicotti* (Page 1975), and *E. smithi* (Page & Burr 1976), *E. proeliare* fed more heavily on small crustaceans and less heavily on insects other than chironomids. This is probably a

TABLE 4.—Stomach contents of *Etheostoma proeliare* from Max Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred				Mean Number of Food Organisms per Stomach			
	<21 mm (19)	21–25 mm (23)	26–30 mm (53)	>30 mm (23)	<21 mm (19)	21–25 mm (23)	26–30 mm (53)	>30 mm (23)
Arachnida								
Acarina	5.3	....	....	....	0.05	....	....	....
Crustacea								
Cladocera	21.1	56.5	37.0	34.8	0.21	3.00	6.31	0.96
Ostracoda	....	8.7	3.7	8.7	....	0.13	0.04	0.09
Copepoda	73.7	87.0	79.6	82.6	2.53	8.56	12.22	5.65
Isopoda								
Asellidae								
Asellus	5.3	4.4	1.9	34.8	0.05	0.04	0.02	0.83
Lirceus	....	....	1.9	13.0	....	....	0.02	0.13
Amphipoda								
Hyalellidae								
Hyalella	....	17.4	22.2	13.0	....	0.35	0.56	0.22
Chilopoda	....	....	1.9	....	....	....	0.02	....
Insecta								
Collembola								
Sminthuridae	....	....	3.7	4.3	....	....	0.04	0.04
Isotomidae	....	....	1.9	....	....	....	0.04	....
Ephemeroptera	....	4.3	11.1	....	....	0.04	0.13	....
Hemiptera								
Corixidae	5.3	4.3	1.9	....	0.11	0.04	0.02	....
Diptera								
Tipulidae	....	4.3	....	....	....	0.04	....	....
Chaoboridae	5.3	8.7	....	....	0.05	0.13	....	....
Chironomidae	100.0	69.6	75.9	95.7	8.05	4.35	3.87	22.13

function of the small body and mouth of *E. proeliare,* which makes ingestion of large insects (e.g., caddisflies and stoneflies) difficult, and also of the habitat in which *E. proeliare* lives. Small crustaceans are common in vegetation; insects such as mayflies, caddisflies, and stoneflies are much more common in rocky habitats.

As in most darters studied, chironomid larvae were an extremely important food item to *E. proeliare* of all sizes. Small crustaceans, especially copepods and cladocerans, were also important to *E. proeliare* of all sizes. In other darters (those cited above) small crustaceans were important to small individuals, but decreasingly so with an increase in the size of the darter. Isopods were consumed in significant amounts only by *E. proeliare* over 30 mm in standard length.

Chironomids and copepods were important diet items every month of the year (Table 5). Cladocerans were most important in the fall, isopods from March to September, and amphipods from May to December.

Rice (1942: 8–9) examined the stomach contents of 20 specimens of *E. proeliare* from Reelfoot Lake near Samburg, Tennessee. She found that mayflies made up 50 percent of the diet, copepods 35 percent, ostracods 10 percent, mosquito larvae 3 percent and leafhoppers 2 percent. No leafhoppers were found in the stomachs of Max Creek specimens, but springtails were present. The presence of leafhoppers and springtails indicates possible surface feeding by *E. proeliare* since both of these insect groups are terrestrial and would become submerged only accidentally.

INTERACTIONS WITH OTHER ORGANISMS

Competition

Other than *E. proeliare* the only darters regularly encountered at the study area were *E. chlorosomum* and *E. gracile*. *E. gracile* was usually in the vegetated areas most heavily occupied by *E. proeliare* but was much less common. *E. chlorosomum* was in deeper, clay-bottom pools. All three of these species lay their eggs on vegetation, but there is no evidence of competition for spawning sites in Max Creek where there is an abundance of dead leaves and vegetation in the spring.

The restricted distribution of *E. proeliare* in southern Illinois is difficult to understand. Many apparently suitable habitats in southern Illinois are uninhabited by *E. proeliare*. *E. gracile* and *E. chlorosomum* are much more widespread and common.

Predation

As potential predators of *E. proeliare,* 7 *Esox americanus* (84–155 mm), 1 *Noturus gyrinus* (84 mm), 4 *Aphredoderus sayanus* (35–66 mm), 1 *Centrarchus macropterus* (95 mm), 1 *Micropterus salmoides* (70 mm), 5 *Lepomis cyanellus* (75–129 mm), 4 *L. macrochirus* (56–95 mm), 2 *L. megalotis* (50–56 mm), and 1 *Cottus carolinae* (68 mm) were preserved and later examined. The only ingested fish found were 2 *Aphredoderus sayanus* in the stomachs of 2 *Esox americanus*.

Parasitism

Of the 118 *E. proeliare* from which stomach contents were examined, two each contained one par-

Table 5.—Stomach contents of *Etheostoma proeliare* from Max Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred												Mean Number of Food Organisms Per Stomach											
	Jan. (8)	Feb. (8)	Mar. (7)	Apr. (8)	May (10)	June (10)	July (13)	Aug. (10)	Sept. (10)	Oct. (18)	Nov. (8)	Dec. (8)	Jan. (8)	Feb. (8)	Mar. (7)	Apr. (8)	May (10)	June (10)	July (13)	Aug. (10)	Sept. (10)	Oct. (18)	Nov. (8)	Dec. (8)
Arachnida																								
Acarina	....	....	....	....	....	10.0	....	....	....	....	....	....	....	....	....	....	....	0.10	....	....	....	....	....	....
Crustacea																								
Cladocera	....	25.0	....	37.5	....	50.0	....	30.0	90.0	83.3	75.0	25.0	....	0.25	....	0.38	....	0.50	....	0.30	27.90	7.06	1.63	0.50
Ostracoda	....	....	....	....	....	10.0	....	....	10.0	22.2	....	....	....	....	....	....	....	0.10	....	....	0.10	0.28	....	....
Copepoda	100.0	87.5	71.4	75.0	70.0	70.0	46.2	80.0	100.0	88.9	100.0	100.0	19.75	28.75	5.00	4.38	3.90	3.00	1.31	2.10	6.10	5.33	8.38	30.75
Isopoda																								
Asellidae																								
Asellus	....	....	14.3	37.5	10.0	40.0	7.7	....	10.0	....	....	....	....	....	0.14	0.63	0.10	1.30	0.08	....	0.10	....	....	....
Lirceus	....	....	....	37.5	10.0	....	....	....	....	....	....	....	....	....	....	0.38	0.10	....	....	....	....	....	....	....
Amphipoda																								
Hyalellidae																								
Hyalella	....	....	....	....	10.0	20.0	7.7	10.0	50.0	38.9	12.5	12.5	....	....	....	....	0.10	0.50	0.08	0.10	1.10	1.22	0.13	0.13
Chilopoda	....	....	....	....	....	....	....	....	....	....	....	12.5	....	....	....	....	....	....	....	....	....	....	....	0.13
Insecta																								
Collembola																								
Sminthuridae	....	25.0	14.3	....	....	....	....	....	....	....	....	....	....	0.25	0.14	....	....	....	....	....	....	....	....	....
Isotomidae	12.5	....	....	....	....	....	....	....	....	....	....	....	0.25	....	....	....	....	....	....	....	....	....	....	....
Ephemeroptera	12.5	....	....	....	....	....	....	10.0	10.0	22.2	....	....	0.13	....	....	....	....	....	....	0.10	0.10	0.28	....	....
Hemiptera																								
Corixidae	....	....	....	....	....	....	15.4	....	10.0	....	....	....	....	....	....	....	....	....	0.15	....	0.10	....	....	....
Diptera																								
Tipulidae	....	....	....	....	....	....	....	....	10.0	....	....	....	....	....	....	....	....	....	....	....	0.10	....	....	....
Chaoboridae	....	....	....	....	....	....	23.1	....	....	....	....	....	....	....	....	....	....	....	0.31	....	....	....	....	....
Chironomidae	100.0	100.0	100.0	87.5	100.0	100.0	100.0	90.0	90.0	33.3	75.0	62.5	1.88	11.75	6.29	26.38	20.70	11.80	13.77	4.50	2.50	0.61	2.25	1.00

asitic nematode and two each contained one spiny-headed worm *(Acanthocephalus)*. An unidentifiable tapeworm plerocercoid was found in a specimen collected 17 June 1976. The only external infestation was a protozoan parasite *(Myxosoma)* found on 8 specimens collected in May and June of 1976.

Specimens examined for external parasites from throughout the range of *E. proeliare* revealed infestation with a fluke [two collections—KU 15232 (Missouri); TCWC 4025.4 (Texas)] and a protozoan [four collections—CU 37538 (Mississippi); FSU 14342 (Arkansas); MSU 6058 (Tennessee); TCWC 4068.8 (Texas)]. A collection of *E. proeliare* from Amber Creek, Alexander County, Illinois (INHS 6042) made on 7 July 1964 contained specimens infected with a parasitic copepod *(Lernaea)*.

Bangham & Venard (1942: 31) examined 15 specimens of *E. proeliare* from Reelfoot Lake, Tennessee, for parasites. An acanthocephalan, *Leptorhyncoides thecatum*, was found in 9 of the 15 specimens; a digenetic trematode, *Neochasmus umbellus* was found in 3 of the 15; and a nematode, *Contracaecum spiculigerum*, in 1 of the 15.

Hybridization

No natural darter hybrid combinations involving *E. proeliare* have been reported. Successful artifica crosses of *E. proeliare* have been made with the following species: *Ammocrypta vivax, Percina nigrofasciata, P. sciera,* and *E. stigmaeum* (Hubbs 1959) and *E. lepidum* and *E. spectabile* (Hubbs 1967).

SUMMARY

Life-history information on *E. proeliare* collected in Max Creek between 25 October 1975 and 9 October 1976 is summarized in Table 6.

TABLE 6.—Summary of life-history information on Max Creek *Etheostoma proeliare*.

Characteristic	Life-History Data
Principal habitat	Leaf-laden and/or vegetated, sluggish water bodies
Age at reaching sexual maturity	1 year
Age at first spawning	1 year
Size at reaching sexual maturity	All spring-collected individuals regardless of size were potential spawners
Sexual dimorphism	Adult males average smaller, have red-orange color in their first dorsal fins, develop expanded cup-like appendages on their pelvic fins and have longer heads, longer postdorsal lengths, deeper caudal peduncles, and longer pelvic, pectoral, anal and second dorsal fins
Breeding tubercles	Present on undersides of pelvic fins and both sides of anal fin in males only
Description of genital papillae	Females have a deeply forked, bilobed papilla; males have a pointed, tubular papilla
Number of mature ova in preserved females	26–116
Description of egg	0.7 mm across, translucent, adhesive and shaped like a half doughnut
Spawning period	From mid-March to early June
Spawning habitat	Relatively shallow, sluggish water with accumulations of dead leaves, filamentous algae, or other aquatic plants
Egg deposition sites	Dead leaves, twigs, sides of rocks, filamentous algae
Number of eggs laid per spawning act	1–3
Spawning position	Both male and female inverted or in vertical position, male mounted on back of female
Egg guarding	None observed; probably no parental care
Incubation period	131 ± 9 hours at 22°–23°C, 211 ± 23 hours at 20°C, 300 ± 9 hours at 15°C
Influence of sex on growth rate	Both sexes grew at approximately the same rate
Density	Up to 5.5 darters/m^2 in vegetated areas
Sex ratio among young	1 male:1 female
Longevity	18 months
Maximum size	36.4 mm standard length
Migrations	None observed
Territoriality	None observed
Principal diet	Chironomid larvae and microcrustaceans

LITERATURE CITED

Bangham, R. V., and C. E. Venard. 1942. Studies on parasites of Reelfoot Lake fish IV. Distribution studies and checklist of parasites. Tennessee Academy of Science Journal 17 (1): 22–38.

Braasch, M. E., and P. W. Smith. 1967. The life history of the slough darter, *Etheostoma gracile* (Pisces, Percidae). Illinois Natural History Survey Biological Notes 58. 12 p.

Burr, B. M. 1978. Systematics of the percid fishes of the subgenus *Microperca,* genus *Etheostoma.* Alabama Museum of Natural History Bulletin, University of Alabama. In press.

Fletcher, A. M. 1957. A rare darter-spawning. Aquarium 26 (6):202–203.

Hay, O. P. 1881. On a collection of fishes from eastern Mississippi. U. S. National Museum Proceedings 3:488–515.

Hubbs, C. 1959. Laboratory hybrid combinations among etheostomatine fishes. Texas Journal of Science 11 (1):49–56.

———. 1967. Geographic variations in survival of hybrids between etheostomatine fishes. Texas Memorial Museum Bulletin 13. 72 p.

Mathur, D. 1973. Some aspects of life history of the blackbanded darter, *Percina nigrofasciata* (Agassiz), in Halawakee Creek, Alabama. American Midland Naturalist 89 (2):381–393.

Page, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps,* in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———. 1975. The life history of the stripetail darter, *Etheostoma kennicotti,* in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

———, and B. M. Burr. 1976. The life history of the slabrock darter, *Etheostoma smithi,* in Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 99. 12 p.

———, and P. W. Smith. 1970. The life history of the dusky darter, *Percina sciera,* in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes 69. 15 p.

———, and ———. 1971. The life history of the slenderhead darter, *Percina phoxocephala,* in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes 74. 14 p.

Petravicz, J. J. 1936. The breeding habits of the least darter, *Microperca punctulata* Putnam. Copeia 1936 (2):77–82.

Rice, L. A. 1942. The food of seventeen Reelfoot Lake fishes in 1941. Tennessee Academy of Science Journal 17 (1):4–13.

Schenck, J. R., and B. G. Whiteside. 1976. Distribution, habitat preference and population size estimate of *Etheostoma fonticola.* Copeia 1976 (4):697–703.

———, and ———. 1977*a*. Food habits and feeding behavior of the fountain darter, *Etheostoma fonticola* (Osteichthyes: Percidae). Southwestern Naturalist 21 (4):487–492.

———, and ———. 1977*b*. Reproduction, fecundity, sexual dimorphism and sex ratio of *Etheostoma fonticola* (Osteichthyes: Percidae). American Midland Naturalist 98 (2):365–375.

Smith, H. M. 1907. The fishes of North Carolina. North Carolina Geological and Economic Survey 2:1–453.

Strawn, K. 1956. A method of breeding and raising three Texas darters. Part II. Aquarium Journal 27 (1):12–14, 17, 31.

Wiley, M. L., and B. B. Collette. 1970. Breeding tubercles and contact organs in fishes: their occurrence, structure and significance. American Museum of Natural History Bulletin 143 (3):145–216.

Williams, J. S. 1976. Spawning behavior of *Etheostoma edwini* (Pisces:Percidae). Association of Southeastern Biologists Bulletin 23 (2):107.

Winn, H. E. 1958*a*. Observations on the reproductive habits of darters (Pisces-Percidae). American Midland Naturalist 59 (1):190–212.

———. 1958*b*. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecological Monographs 28 (2):155–191.

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SOYBEAN SPIDERS: SPECIES COMPOSITION, POPULATION DENSITIES, AND VERTICAL DISTRIBUTION

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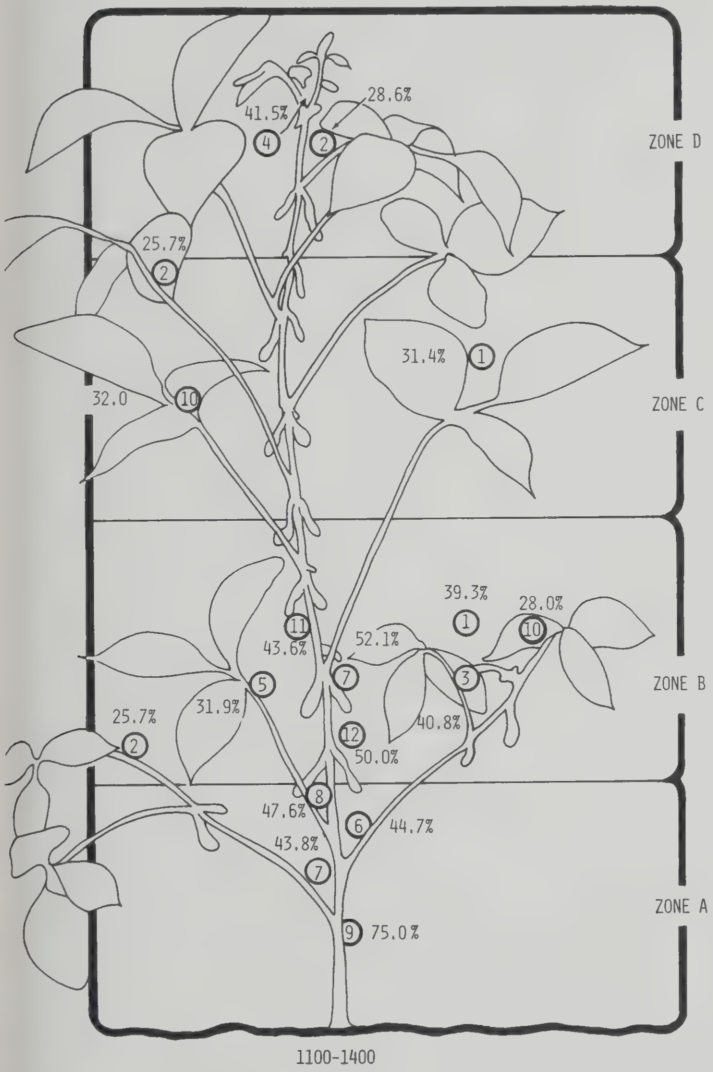

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Soybean Spiders: Species Composition, Population Densities, and Vertical Distribution

Charles D. LeSar and John D. Unzicker

Spiders are receiving considerable attention as potentially important predators of arthropod pests of agricultural crops because of increased interest in the development and use of integrated pest-management systems.

Studies concerning spiders in agricultural crops have been conducted by Chant (1956) and Dondale (1956 and 1958), apples; Putman (1967), peaches; Howell & Pienkowski (1971) and Yeargan & Dondale (1974), alfalfa; Fox & Dondale (1972), hayfields; and Muma (1975), citrus. However, there is a paucity of research on spiders in row crops. The few such studies that have been made are by Whitcomb et al. (1963) and Leigh & Hunter (1969), cotton; and Bailey & Chada (1968), grain sorghum. Investigations of arthropod populations in soybeans, including qualitative lists of spiders present during the growing season, have been carried out by Barry (1973), Neal (1974), and Deitz et al. (1976). However, reports quantifying spider populations, showing colonizing rates, and listing prey preferences of the dominant spider species in row crops are lacking. The data that will be presented here should help to fill the void of information on spiders in one of the most important row crops, soybeans.

The investigation was divided into two parts. The first deals with colonization times and rates, population densities, and species composition within the soybean field from the time the soybean plants appear above the ground in late May until they are harvested in the fall, usually in late September. In the second part determinations were made of the primary locations of the major spider species on the soybean plant and of the diurnal movements of spiders where possible. Sampling for information on species locations and diurnal movements was not begun until the soybean plant had reached maturity and colonization by the major spider species was relatively complete. These events occurred about the 2nd week of August, and sampling was continued until 15 September.

We would like to thank Drs. W. H. Luckmann, P. W. Price, and M. Kogan for their critical appraisals of this report and Dr. W. LaBerge, D. Webb, and J. Bouseman, who identified insect prey. Lloyd LeMere, Technical Illustrator, and Larry Farlow, Technical Photographer, both of the Illinois Natural History Survey, drew and photographed the illustrations. Robert M. Zewadski, Technical Editor of the Survey, edited the report for publication.

MATERIALS AND METHODS

Species Composition and Population Densities

Five different fields were sampled, two adjacent fields in 1975 and three widely separated fields in 1976. All were located in Tazewell and Champaign counties. Tazewell County, in west-central Illinois, and Champaign County, in east-central Illinois, are approximately 85 miles apart. All of the fields had been in corn-soybean rotation for several years. Each of them had some grassy or uncultivated areas adjacent on the south and/or west. No insecticides were applied to the soybeans during the growing season; however, preemergence herbicides were used. The summer prevailing wind is southwest with shifts to the west or northwest when thunderstorms occur. Large fields were selected (15–28 ha) to minimize the possibility of any unwanted encroachment of spiders from peripheral areas that would bias the colonization data.

A weekly series of 30 samples was taken in rows of each soybean field by means of a D-Vac suction machine, having a suction head 357 mm in diameter. Each sample therefore covered 357 mm along the row. This sampling method was selected after comparing quantitatively samples taken by D-Vac with samples taken by sweep net and by beat cloth into which the spiders are shaken or beaten from the vegetation. The sweep net yielded 34 percent fewer spiders and the beat cloth 19 percent fewer spiders than did the D-Vac method. Fig. 1 shows the correlation between the beat cloth and the D-Vac samples ($r = 0.864$), with the slope of the regression line indicating that the D-Vac retrieves about 1.2 more spiders than does the beat cloth from 5.25 m of soybean row. Papers by Dumas et al. (1964), Howell & Pienkowski (1971), and Shepard et al. (1974) give data on the limitations and timing of various sampling methods.

Transect samples taken in 1975 showed a much higher spider population (up to three times greater) during the early portions of the growing season in the first 20 peripheral rows (about 20 m wide) than

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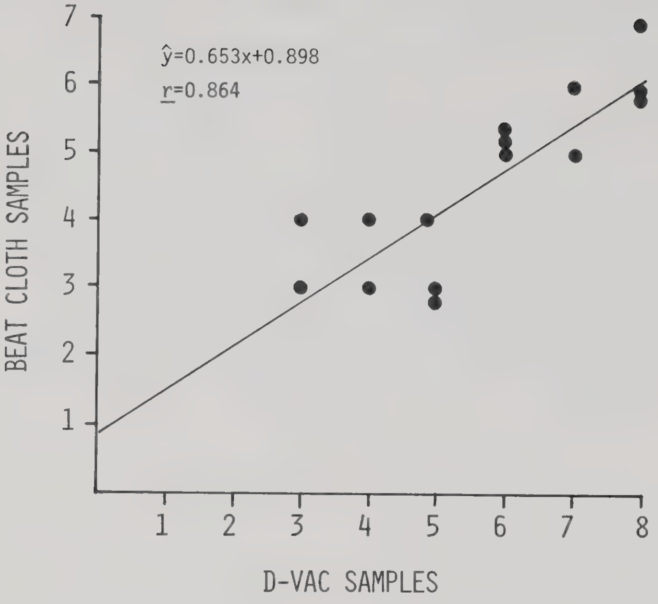


Fig. 1.—Correlation between the number of spiders collected by two sampling methods in Illinois soybean fields during 1975 and 1976.

in any other area of the fields. All samples for the study of population density and species composition were taken in random locations in the centers of fields, and these sites were noted so that no field was sampled more than once in a specific site.

The fields from which spider data were collected were planted from 15 to 20 May, the plants emerging from the ground during the last few days of May. The first spiders were collected in the experimental fields on 13 June 1975 and 15 June 1976, when the plants were about 2½ weeks old and stood 100–120 mm high.

To determine the differences between the spider-species composition in one field and that of another and to determine how much variation occurred in species composition from 1 year to the next, an analysis of species diversity was made.

According to Hurlbert (1971), species diversity is a function of the number of species present (species richness or abundance) and the frequency of occurrence of individuals of the various species (species evenness or equitability). We used two indices to analyze the diversity of spider communities in soybeans: H′ (Shannon & Weaver *in* Southwood 1971) and α (Margalef *in* Southwood 1971). Sorensen's (*in* Southwood 1971) quotient of similarity (QS) was used to compare species richness among different fields.

Species diversity, H′, was computed by this formula:

$$H' = -\sum_{i=1}^{S} p_i \log_e p_i$$

in which S is the number of species and p_i is the proportion of the total number of individuals represented by the species i, such that $p_i = N_i/N$.

The computation of α was based on the simplified form proposed by Margalef (*in* Southwood 1971):

$$\alpha = (S - 1)/\log_e N$$

in which S is the number of species in the sample and N is the number of individuals.

Sorensen's quotient of similarity was computed according to Southwood (1971):

$$QS = 2j/(a + b)$$

in which j is the number of species common to the two habitats, and a and b are the numbers of species in habitats A and B, respectively.

Vertical Distribution

The average soybean plant is approximately 1 m tall at maturity. We divided the plant into four vertical zones of about 250 mm each for stratified sampling. These zones, starting from the bottom of the plant, were designated A, B, C, and D. A portable D-Vac with a reducer cone measuring 220 mm in diameter was used to suck the spiders from each zone of the plant. The complex structure of the mature soybean plant makes it difficult to obtain representative samples from each zone of a single plant; therefore, the samples were collected from plants covering 15.75 m in a row. Four adjacent soybean rows were sampled in each of four daily time periods, one row for each of the vertical zones. This technique was necessary because sampling one zone of the plants could disturb the spider population on the remainder of the plants to the extent that normal stratification would not be present for subsequent samples. It should be noted that spiders may drift down from the upper zones as the lower ones are being sampled. Samples were taken during four times of day, 0800–1000, 1100–1400, 1600–1800, and 2000–2100 CDT, to determine whether spider species change positions on the plants during different time periods. Because heavy dew often prevented sampling, fewer samples were taken during the early morning and the evening hours than were taken at other times.

RESULTS AND DISCUSSION

Species Composition and Population Densities

The soybean field presents an unusual habitat. At the beginning of the growing season the field has a large area of soil without vegetation and with a very small resident population of arthropods, consisting mostly of ground-dwelling species. The soybeans create a temporary plant community with rapidly changing environmental conditions. The presence of plants gradually ameliorates the climate from that of a barren desertlike habitat with extreme exposure to the elements and little shelter for animals to that of a habitat in which most of the soil is shaded, humidity levels increase, and there is an abundance of food and shelter for the arthropod population.

Sampling the newly emerged soybean plant in early June indicates virtually no overwintering spider species that live primarily on the foliage. The field is essentially a monocultural island surrounded by hayfields, pastures, and fields planted in other crops. Therefore, the theory of island biogeography developed by Mac Arthur & Wilson (1967) provides, with modifications, the basis for this investigation in which the spider population is monitored to determine immigration into the soybean field. Price & Waldbauer (1975) have discussed crop islands in agricultural ecosystems and their possible roles in pest management. Price (1976) has recently written on insect colonization in soybeans, emphasizing the potential importance of island biogeography concepts as they apply to row crops.

Nearly all of the arthropods, especially those species found primarily on the foliage, find their way into the field during the growing season by migration. Migration is accomplished either by flight, in the case of most insects, or by ballooning, in the case of the majority of the spiders (Duffey 1962). The small sizes of most foliage-inhabiting spiders preclude their ability to disperse far enough into a field from the borders to colonize any area other than the edges except by ballooning. Thus, the arthropods that are found in the field as the soybean plants are becoming established in early June are there as a direct result of colonization from adjacent areas or of ballooning or flying greater distances. Over 4,100 spider specimens (from 30 weekly collections and from vertical sampling) representing 19 families and 77 species were collected from soybean foliage during two growing seasons (Table 1).

The data from three combinations of fields and/or years were analyzed and compared for species diversity. Table 2 shows α, H′, and QS values and the correlation of species diversity from one field to another and from 1975 to 1976. All values were obtained from counts of all spiders collected from each field throughout the entire growing seasons of 1975 and 1976.

A comparison of data from fields A and B of 1975 with data from all fields of 1976 shows that species diversity was higher in 1975, when a very wet growing

TABLE 1.—Spiders collected from soybean foliage in Illinois during 1975 and 1976.

Agelenidae
- *Agelenopsis kastoni* Chamberlin & Ivie
- *Agelenopsis* sp.
- *Cicurina pallida* Keyserling

Anyphaenidae
- *Anyphaena pectorosa* L. Koch
- *Aysha gracilis* (Hentz)
- *Oxysoma cubana* Banks
- *Wulfila saltabunda* (Hentz)

Araneidae
- *Acanthepeira stellata* (Walckenaer)
- *Araneus quttalatus* (Walckenaer)
- *Araniella displicata* (Hentz)
- *Argiope aurantia* Lucus
- *Argiope trifasciata* (Forskal)
- *Neoscona arabesca* (Walckenaer)

Clubionidae
- *Castianeira descripta* (Hentz)
- *Chiracanthium inclusum* (Hentz)
- *Chiracanthium mildei* Koch
- *Clubiona abbotii*[a] L. Koch

Dictynidae
- *Argenna obessa* Emerton

Gnathosidae
- *Drassylus depressus* (Emerton)
- *Gnathosa sericata* (Koch)
- *Sergiolus capulatus* (Walckenaer)
- *Zelotes laccus* (Barrows)

Hahniidae
- *Neoantistea agilis* (Keyserling)

Linyphiidae
- *Frontinella pyramitela* (Walckenaer)
- *Meioneta fabra* (Keyserling)
- *Meioneta micaria*[a] (Emerton)
- *Meioneta unimaculata* (Banks)
- *Microlinyphia pusilla*[a] Sundevall
- *Tennesseellum formicum* (Emerton)

Lycosidae
- *Pardosa milvina*[a] (Hentz)

Micryphantidae
- *Catabrithorax plumosus* (Emerton)
- *Ceratinops rugosa* (Emerton)
- *Ceratinopsis laticeps* (Emerton)
- *Ceratinopsis nigriceps* Emerton
- *Eperigone tridenta* (Emerton)
- *Eperigone trilobata* (Emerton)
- *Erigone atra* Blackwall
- *Erigone autumnalis* Emerton
- *Grammonota inornata* Emerton
- *Tapinocyba scopulifera* (Emerton)
- *Walckenaera vigilax* (Blackwall)

Mimetidae
- *Mimetus epeiroides*[a] Emerton

Oxyopidae
- *Oxyopes salticus*[a] Hentz
- *Oxyopes scalaris* Hentz

Philodromidae
- *Philodromus abbotii* Walckenaer
- *Philodromus aureolus*[a] (Olivier)
- *Philodromus washita* Banks

Pisauridae
- *Pisaurina brevipes* (Emerton)
- *Pisaurina mira* (Walckenaer)

Salticidae
- *Agassa cyanea* (Hentz)
- *Eris marginata* (Walckenaer)
- *Eris pineus* (Kaston)
- *Habronattus rutherfordi* (Gertsch & Mulaik)
- *Hentzia palmarum* (Hentz)
- *Metaphidippus galathea* (Walckenaer)
- *Metaphidippus protervus*[a] (Walckenaer)
- *Phidippus audax*[a] (Hentz)
- *Tutelina elegans* (Hentz)

Tetragnathidae
- *Mimognatha foxi* (McCook)
- *Tetragnatha laboriosa*[a] Hentz
- *Tetragnatha straminea* Emerton

Theridiidae
- *Paidisca unimaculatum* (Emerton)
- *Theridion albidium* Banks
- *Theridion frondeum* Hentz
- *Theridion neshamini*[a] Levi
- *Theridion rabuni* Chamberlin & Ivie
- *Theridula opulenta* (Walckenaer)

Thomisidae
- *Thanatus formicinnus* (Oliver)
- *Tibellus oblongus*[a] (Walckenaer)
- *Misumena calycina* (Linnaeus)
- *Misumenoides formocipes* (Walckenaer)
- *Misumenops asperatus*[a] (Hentz)
- *Xysticus auctificus* Keyserling
- *Xysticus elegans* Keyserling
- *Xysticus ferox* (Hentz)
- *Xysticus fraternus* Banks

Uloboridae
- *Uloborus glomosus* (Walckenaer)

[a] Denotes the most abundant species.

Table 2.—An analysis of species diversity and quotients of similarity for Illinois soybean fields sampled during 1975 and 1976. Data from fields A and B of 1975 were combined and compared with combined data from fields A and B of 1976 to compare species diversity from one year to the next.

Species Diversity

Field	Year	Number of Specimens	Species	Alpha	H′	QS
A & B	1975	785	74	10.95	1.17	0.54
A & B	1976	860	29	4.14	0.77	
A & B	1976	860	29	4.14	0.77	0.69
C	1976	326	23	3.80	0.69	
A	1975	402	57	9.34	1.17	
B	1975	383	48	7.90	1.11	
A	1976	503	24	3.70	0.80	
B	1976	357	24	3.91	0.68	
C	1976	326	23	3.80	0.69	

Quotients of Similarity

Field and Year	Field A 1975	Field B 1975	Field A 1976	Field B 1976	Field C 1976
A 1975	1.00				
B 1975	0.59	1.00			
A 1976	0.57	0.61	1.00		
B 1976	0.49	0.61	0.79	1.00	
C 1976	0.45	0.51	0.68	0.64	1.00

season suppressed the dominant species, causing a greater evenness of distribution among the remaining species in the population. In 1976, when a relatively dry summer allowed a build-up of the dominant species, *Tetragnatha laboriosa*, the species in the total sample became very uneven in their abundance, causing the diversity index (H′) to decline. Since α is more sensitive to the presence of rare species, the decline was greater in this value (63 percent) than it was in the H′ value (34 percent). Differences in species richness (2.5 times more species were collected in 1975 than were taken in 1976) also had significant effects on H′, α, and QS values.

A second analysis consisted of comparing fields A and B in Tazewell County with field C in Champaign County in 1976. The data indicate a greater similarity in spider populations between widely separated fields during one growing season (QS = 0.69) than that between fields that are close to one another but are sampled during two growing seasons (QS = 0.54).

The third analysis was a comparison of all fields sampled during both years. Fields A and B of 1975 had higher H′ and α values than had fields A, B, and C of 1976. Here again differences in species evenness are reflected in the discrepancies between α and H′ for fields A and B of 1976. The QS value for fields A and B of 1975 was relatively low even though the fields were close to one another. This fact suggests that differences in the adjacent habitats played an important role in species composition. Field A had brush and trees on the north, east, and west borders and an open area only on the south side, while field B, one-quarter mile to the east and south, had no brush or trees nearby. Field A of 1976 was one-half mile southeast of field B of 1975 but had much lower species-diversity values. The H′ and α values of field A of 1976 were similar to those of fields B and C of 1976, which were 15 and 90 miles away, respectively. Field B of 1976 and field C of 1976 had nearly identical H′ values. These two fields had very similar peripheral areas and soil types, suggesting that adjacent undisturbed areas have a great impact on the species diversity of spiders in soybean fields in a growing season.

Table 3 shows that among the earliest spider colonizers are members of the families Tetragnathidae, Salticidae, Oxyopidae, Thomisidae, and Theriidae.

Table 3.—Average abundances of the most frequently occurring spider species found per 10.5 m of row of soybeans throughout the growing seasons of 1975 and 1976.

Species	June 1–15 '75/'76	June 15–30 '75/'76	July 1–15 '75/'76	July 15–30 '75/'76	Aug. 1–15 '75/'76	Aug. 15–30 '75/'76	Sept. 1–15 '75/'76	Sept. 15–30 '75/'76
Tetragnatha laboriosa	2/1	3/3	6/3	5/7	3/12	5/25	18/61	20/26
Misumenops asperatus	0/0	0/0	0/1	1/1	2/2	4/3	3/4	1/3
Clubiona abbotii	0/0	0/0	0/0	1/1	3/1	2/2	4/3	2/2
Philodromus aureolus	0/0	0/0	0/1	0/1	2/2	2/3	2/3	0/2
Meioneta micaria	1/1	1/1	0/1	1/0	1/2	0/3	0/2	0/2
Phidippus audax	0/0	0/0	0/0	1/1	2/2	3/1	1/1	1/0
Metaphidippus protervus	0/0	1/1	0/2	1/1	3/1	1/2	1/1	2/2
Microlinyphia pusilla	0/0	0/0	0/0	1/0	2/2	3/4	2/7	2/3
Theridion neshamini	0/0	1/1	1/0	1/1	1/1	1/1	2/0	0/0
Pardosa milvina	0/0	0/0	2/0	1/1	1/1	2/1	2/1	4/0
Tibellus oblongus	1/0	0/0	1/0	1/2	2/1	0/1	1/2	0/0
Oxyopes salticus	0/0	1/0	1/1	0/1	1/2	1/1	1/2	0/0
Mimetus epeiroides	0/0	0/0	0/0	1/0	1/1	1/1	0/1	0/0

hese early arrivals are exposed to the greatest en-ironmental stress, and because colonization of the eld by insects, which are their prey, is also still in ts early stages (Price 1976), food sources are often iscontinuous. Samples indicate that spiders are sually the first major predators to be found con-istently in the soybean field. The data in Table 3 uggest that some spider species suffer extinction in oybean fields during the early part of the growing eason, because heavy rains occur frequently and the mall soybeans afford little protection. The lack of ontinuous food supplies affects small ballooning in-tars more than larger instars, because small individuals have had little opportunity to feed and build up nergy reserves which would allow them to survive long periods between feedings (Miyashita 1968). Micryphantidae were found on the plants early in the season, but they are essentially ground spiders, which usually overwinter in the crop debris, and are only temporary inhabitants.

Cloudsley-Thompson (1962) suggests that plants are major modifiers of the macroclimate and that the structural complexity of the plant cover will determine, to a large degree, the microclimates experienced by arthropods. The spiders that arrive later in the growing season find a habitat greatly changed from the harsh environment encountered by the early colonizers. Therefore, the rate of successful colonization is controlled, in part, by the rate of plant growth. Those spiders that arrive later in the season find not only a more hospitable habitat, but also increased numbers of prey to feed upon (Carner et al. 1974; Price 1976).

Luczak (1963) used a grouping technique in which spider species that constituted more than 40 percent of the population were called dominants, those comprising 15–20 percent were classed as influents, and the remainder were classed as accessories. Only one species, *T. laboriosa,* reached the dominant level, and five species had sufficient numbers to be classed as influents.

The data show that of the 77 species of spiders found on the foliage of the soybean plant during some part of the growing season only 13 species were able to become firmly established. The criterion for establishment of a species was whether it was collected on a regular basis. If a species was collected only sporadically during the growing season and it made up less than 0.5 percent of the total population, it was considered an accessory which did not become successfully established. The 13 species considered established species made up more than 94 percent of the population and were collected, usually without interruption, over a major part of the growing season (Table 3). Fig. 2 shows the times of arrival in the field, the percentages of the population they represented, and their fluctuations in abundance during the growing season in 1975 and 1976 of the six most common species.

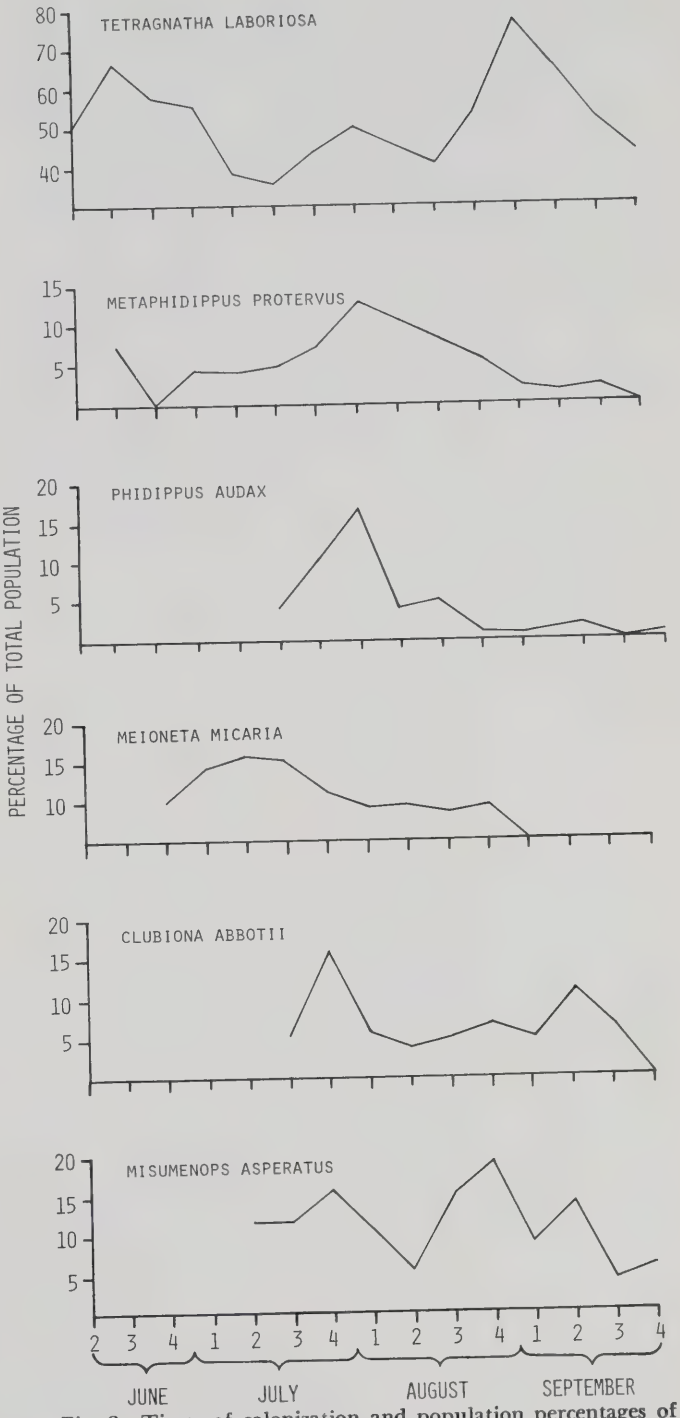


Fig. 2.—Times of colonization and population percentages of the six most common spider species found in Illinois soybeans during 1975 and 1976.

The entire summer of 1975 was very rainy, and populations of the major web builder, *T. laboriosa,* were severely depressed (Table 3) as compared with its population densities in 1976, which had a considerably drier growing season. Data indicate that during August 1975 (rainfall was 47 percent above normal) *T. laboriosa* represented only 22 percent of the total population as compared with 46 percent of the total population in 1976, when August was much drier (about 50 percent below normal). August is the reproductive period for *T. laboriosa,* and the rain apparently interfered with the emerging young and their dispersal. Another web builder, *Microlinyphia pusilla,* made up only 2 percent of the total population in 1975, while it constituted 7 percent of the population in 1976. Fig. 3 compares spider population densities in different fields in 1975 and 1976 and illustrates the effect in 1975 of the above-normal rainfall on web builders. The major species of hunting spiders, including *Metaphidippus protervus, Phidippus audax, Clubiona abbotii, Philodromus aureolus,* and *Misumenops asperatus,* had populations considerably higher in 1975 than 1976, suggesting that heavy rainfall does not appreciably interfere with their establishment in soybean fields.

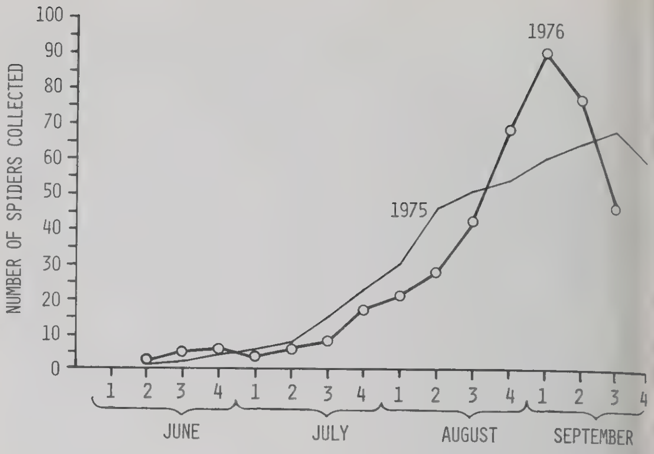


Fig. 3.—Mean numbers of spiders collected per 10.5 m of soybean row in Illinois during the growing seasons of 1975 and 1976.

Only after 15 July, when the plants averaged 600–700 mm in height and there was an abundance of prey available (Shepard et al. 1974; Carner et al. 1974; Price 1976), was there a steady, uninterrupted increase in numbers of spider species. At that time the foliage afforded protection from inclement weather and caused changes in soil temperature and humidity levels (Turnbull 1973). Maximum species numbers occurred during August (Fig. 4) at about the time of the maturation of the soybean plant in central Illinois. Maximum spider population densities occurred somewhat later in early September

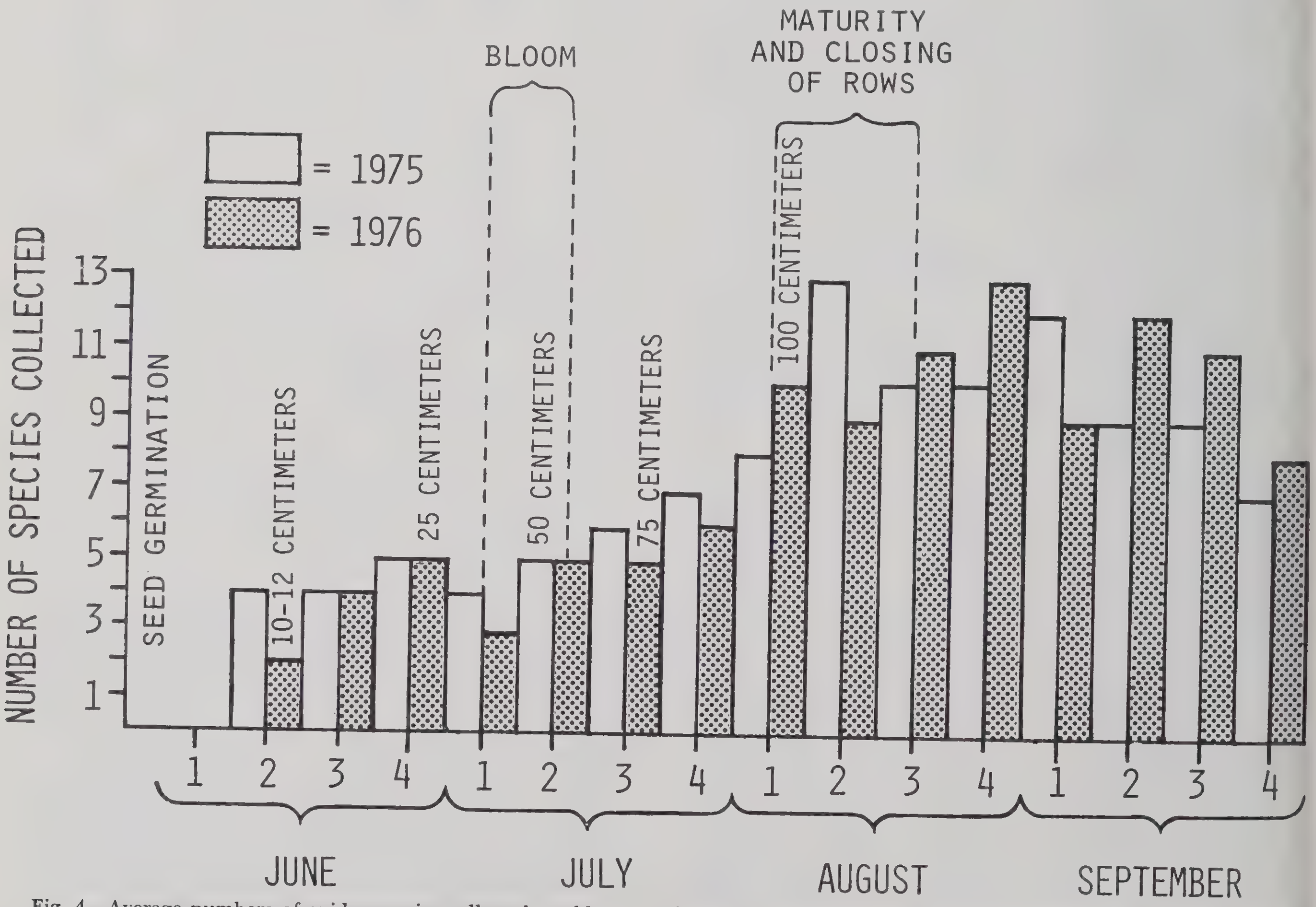


Fig. 4.—Average numbers of spider species collected weekly on soybeans in Illinois during the growing seasons of 1975 and 1976. Stages of development of the soybean plant are also shown.

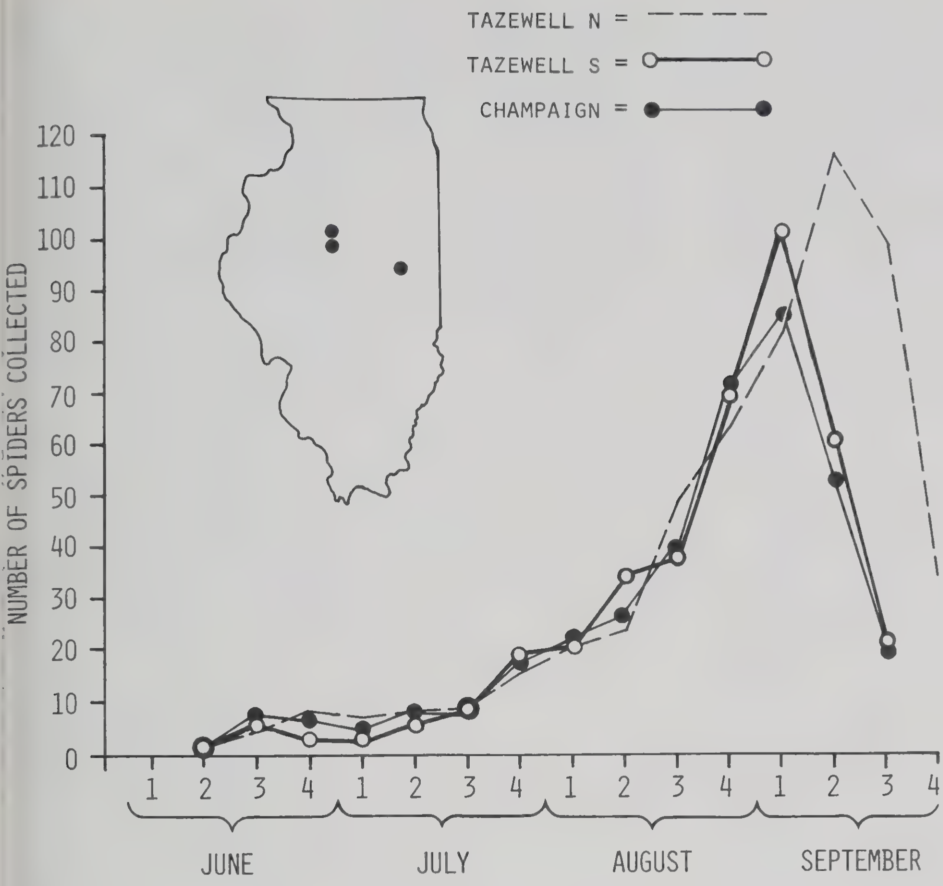


Fig. 5.—Mean numbers of foliage spiders collected per 10.5 m of row in three Illinois soybean fields during 1976.

(Fig. 3 and 5). Average abundances of the 13 spider species most commonly collected during the growing season are shown in Table 3.

Spider species numbers remained high through the remainder of August, but as the plants reached early senescence, a marked drop occurred in population densities. The major decrease in the population occurred by the time the soybean plant had undergone approximately 10–15 percent (estimated) defoliation and most of the leaves were yellow. Tugwell et al. (1973) indicated a declining population of many major insect species as the soybean is undergoing abscission and defoliation. Turnbull (1966) states that no evidence shows that a shortage of food in some areas caused spiders to leave those areas or that an abundance of food in other areas attracted spiders to those areas. Sampling of peripheral areas around the soybean fields confirmed Turnbull's finding, indicating that no significant amount of spider emigration occurred. This fact suggests that most insect species quickly emigrate to available plants still providing palatable food, leaving the majority of spiders behind. This series of events leaves little for spiders to feed upon and puts them in a situation similar to that of the early colonizers in the spring, little food and little protection as the plant begins to defoliate rapidly. Most evidence suggests that extinction for most of the spider population rapidly follows (Fig. 3 and 5), with some slight emigration to adjacent areas.

Vertical Distribution

The spiders that were collected from each vertical zone of the soybean plant during each of four daily

TABLE 4.—A two-way analysis of variance of the six most common spider species found on soybeans in Illinois during 1975 and 1976.

Source of Variation	Species											
	T. laboriosa		*M. asperatus*		*C. abbotii*		*P. aureolus*		*P. audax*		*M. protervus*	
	P	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*
Zone (Z)	0.002[b]	5.06	0.41ns	0.96	0.51ns	0.77	0.02[a]	3.20	0.0001[c]	8.24	0.01[a]	3.67
Time (T)	0.0001[c]	15.56	0.01[a]	3.79	0.02[a]	3.23	0.13ns	1.91	0.03[a]	3.10	0.008[b]	4.06
Z × T	0.24ns[d]	1.29	0.19ns	1.39	0.44ns	1.01	0.36ns	1.10	0.08ns	1.77	0.78ns	0.62

[a] $0.01 < P < 0.05$. [b] $P < 0.01$. [c] $P < 0.001$. [d] Not significant at the 0.05 level.

time periods were identified and counted. The number of spiders of each species found in each zone during each time period were then analyzed by using a two-way analysis of variance. This analysis determined whether the differences between zones and times of day were significant for the major species of spiders. The analysis was made on the six species most frequently collected during 1975 and 1976 (Table 4). Three of these species, *T. laboriosa, P. audax,* and *M. protervus,* had significant differences in location of the population between the different zones and during the different time periods of the day. Two of the remaining species, *C. abbotii* and *M. asperatus,* had significant differences in location of the population during the different time periods, while the remaining species, *P. aureolus,* had significant differences in population densities only among zones. *P. aureolus* was found mostly in the upper canopy, with 65 percent of its population located in zones C and D. An analysis of variance of the inter-

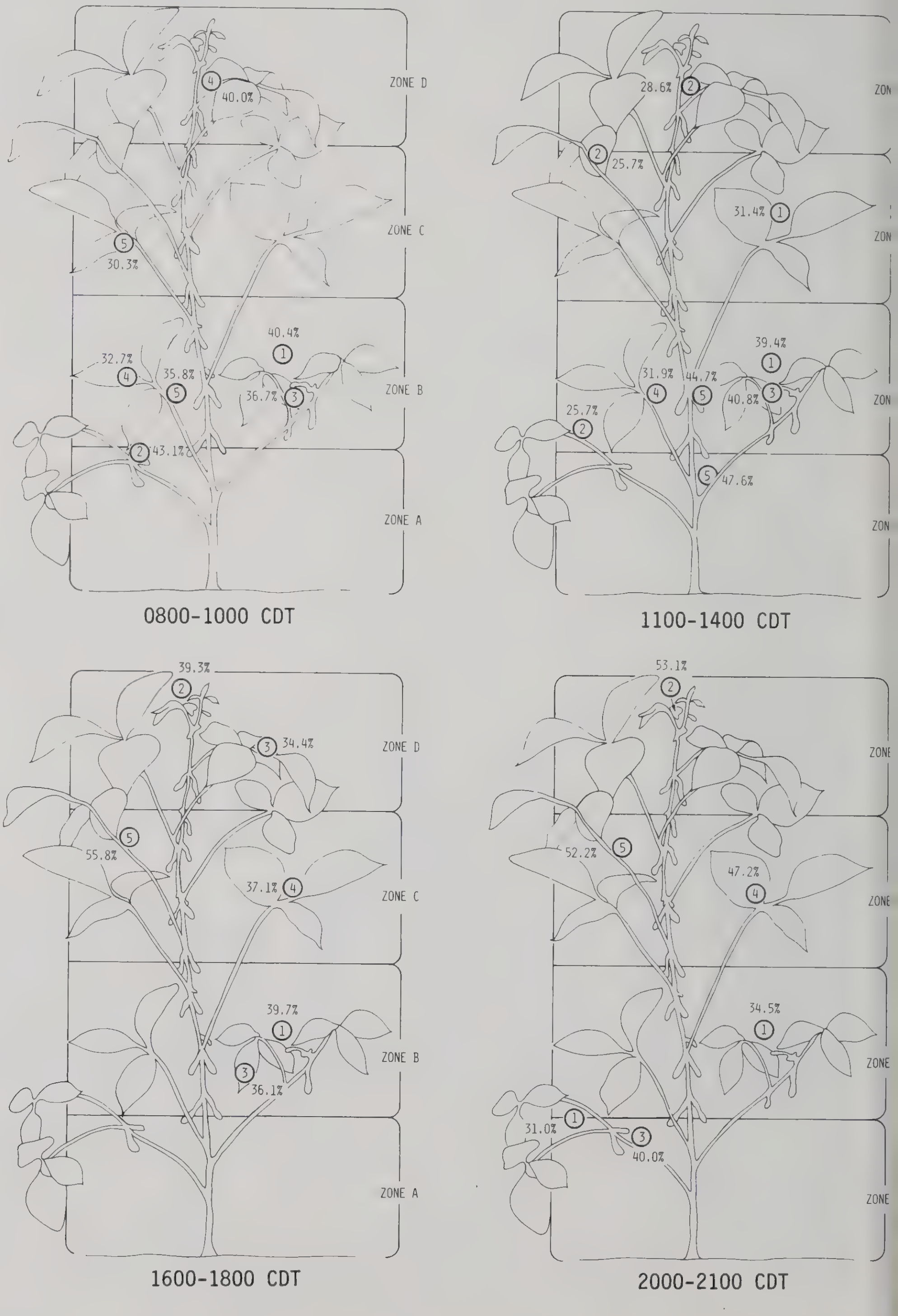


Fig. 6.—Locations of five frequently collected spider species that had significant changes in location on soybean plants during four times of the day in Illinois during 1975 and 1976. Each percentage value represents the percentage found in each plant zone of the total population of each species. The species are: 1. *Tetragnatha laboriosa,* 2. *Misumenops asperatus,* 3. *Clubiona abbotii,* 4. *Phidippus audax,* 5. *Metaphidippus protervus.*

action of zone × time indicated that no significant differences existed at any level for the six species, indicating that the two factors operate independently of each other. Locations of the spider species which had significant movements during four times of the day are recorded in Fig. 6.

Table 5 shows that about two-thirds of the entire spider population was located on the lower half of the soybean plant (zones A and B) regardless of the time of day (see also Fig. 7). These data suggest that prey abundance is probably greater on the lower portions of the plant during most of the day. Enders (1974) found that small insects on plants most often occur near the ground because individuals from higher up may fall and individuals from the detritus food chain climb up to the lower plant parts. *Mimetus epeiroides,* a major predator on spiders, was found almost exclusively on the lower half of the plant. Ninety-six percent of this species was located in zones A and B, suggesting that it feeds on spider prey that is most abundant in this region. Another member of the hunting guild, *Pardosa milvina,* is also prevalent in the lower canopy, about 68 percent of its total population being located in zone A. They are probably concentrated on the lower portion of the plant because they are primarily ground-dwelling spiders foraging for small prey on the soybean plant. Although adults were commonly collected in pitfall traps, every *P. milvina* specimen taken from the foliage was immature, suggesting that prey of the proper size and type was more abundant on the soybean plant than on the ground. Two other hunting species, *Tibellus oblongus* and *Oxyopes salticus,* did not show any marked zone or time preference.

The most noticeable changes in the locations of certain spider species were apparent reactions to heat and humidity stresses encountered by some species that were located in zone D most of the time. Nearly 50 percent of these individuals, mainly *M. protervus, P. audax,* and *T. laboriosa,* move to lower zones during the warmer portions of the day. It is interesting to note that the number of *M. asperatus* and *P. aureolus* individuals (both crab spiders) in the top portions of the plant increased during the same time when *M. protervus, P. audax,* and *T. laboriosa* individuals were moving downward. This upward movement is likely caused by the presence of prey that is preferred by these two species. An additional factor which appears to cause midday downward migration is the destruction of the web of *T. laboriosa* by the first substantial gusts of wind during the morning (C. D. LeSar unpublished data), causing them to seek shelter on a lower part of the plant where environmental conditions are more favorable. The other two web spinners that are commonly encountered, *M. pusilla* and *Theridion neshamini,* are not noticeably affected by wind because their webs have more protection, being positioned on the inner portions of the soybean plant. These two small spiders are mostly found on the lower portions of the canopy, with *M. pusilla* having 93 percent and *T. neshamini* 80 percent of their total populations in zones A and B.

TABLE 5.—Vertical distribution on soybean plants of all spiders collected from five fields in Illinois during 1975 and 1976. Zone A is at the bottom of the plant, and Zone D is at the top.

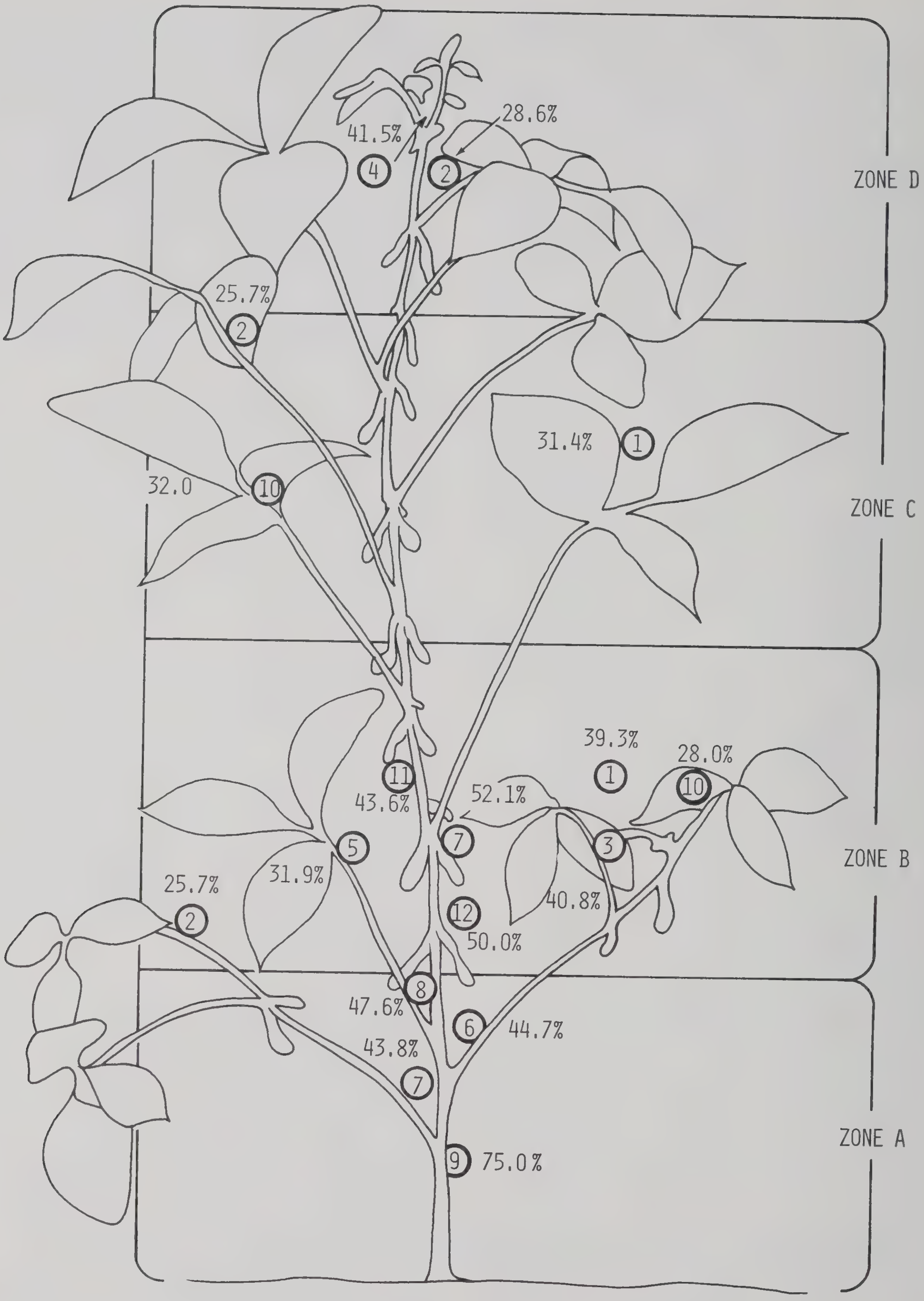
Time	Percentage of Spiders Collected in			
	Zone A	Zone B	Zone C	Zone D
0800–1000	35.7	32.7	21.9	9.7
1100–1400	38.4	32.8	21.9	6.9
1600–1800	35.5	33.6	20.6	10.3
2000–2100	39.3	26.0	20.3	14.4

FURTHER STUDIES

Although many ecologists believe that spiders do not serve a major role in the suppression of harmful insect populations in agricultural crops, we feel that far too little data have been gathered about the interactions of spiders with other arthropods in agricultural crops to draw even the most rudimentary conclusions about their potential impact as predators. Therefore, many important studies remain to be done. A number of researchers have found that in specialized circumstances some spiders can reduce harmful insect populations, but little has been published on their effects on the entire phytophagous insect complex. It is well known that spiders are indiscriminate feeders and that they feed on beneficial as well as pest insect species. Some researchers have suggested that spiders' feeding on major insect predators could negate the beneficial effects of their feeding on insect pests. However, data substantiating this point are not abundant, and additional investigations should be made to determine the validity of this theory.

With the exception of *T. laboriosa,* spiders that are found in soybeans, and presumably other agricultural crops, do not reproduce in the fields during the growing season. Therefore, there is no apparent way to increase the spider population to compensate for an increasing insect population during the growing season. Most spiders encountered in soybean fields have only one generation per year. The main reproductive strategies of the spiders are to lay eggs just before cold weather for overwintering as eggs or as spiderlings, which remain in a cocoon, or to overwinter as subadults which will mature and reproduce early in the next growing season. These subadults can take advantage of abundant prey populations for growth and development. In the fall these immatures usually hibernate until the next spring.

Since the life histories of most temperate-climate spiders span an entire year, from one growing season to another, they cannot respond numerically to fluctuations in prey density. However, there may be a



1100-1400

Fig. 7.—Locations of the 12 most abundant spider species on soybean plants during the 1100–1400 time period and the percentage found in each zone of the total population of each species. The species are: 1. *Tetragnatha laboriosa*, 2. *Misumenops asperatus*, 3. *Clubiona abbotii*, 4. *Philodromus aureolus*, 5. *Phidippus audax*, 6. *Metaphidippus protervus*, 7. *Microlinyphia pusilla*, 8. *Theridion neshamini*, 9. *Pardosa milvina*, 10. *Tibellus oblongus*, 11. *Oxyopes salticus*, 12. *Mimetus epeiroides*.

nctional response to changes in prey density. Ad-itional ballooning of individuals into a field could crease the spider population, but probably not sig-ificantly. One factor that could increase the control f harmful insects by spiders is a high rate of spider rvival due to lessened competition for available od.

Therefore, any studies involving the use of spi-ers to control insect pests would have to develop ur knowledge of spiders as natural control agents. n pest management we must fully understand this ole and protect the spiders from outside disturbance, .g., mowing or spraying.

One important aspect of spider ecology that should e researched to a greater depth is the determination f the species of spiders that are commonly found n major agricultural crops. Questions that should e asked are:

1) Do nearby agricultural crops have a species composition similar to that found on soybeans?
2) Are the major spider species in each crop present in approximately the same abundance, or are there major density variations in the commonly occurring species?
3) Are there any phytosociological limitations where individual species live?
4) Since major crops, such as corn, soybeans, alfalfa, and others, present very different environmental conditions during different times of the growing season, are any of the major spider species excluded as a result?
5) In row crops does the environment of narrow rows allow greater species diversity early in the growing season?

Therefore, we feel that continued research into spider species composition, species diversity, and population densities in different but adjacent field crops is a necessity before more detailed studies on the impact of spiders on pest insects can be made. Luczak (1966) postulates that a given environment will possess a specific association of spider forms; it would be useful to see if this is true.

Once a complete study of species diversity has been made, one can look at individual guilds or species to determine their particular roles as predators. The effect of inclement weather has already been demonstrated as a major problem for some species. There is some indication that web builders are more susceptible to inclement weather than are hunters. On the other hand, Howell & Pienkowski (1971) found that in alfalfa *T. laboriosa* was less affected by cutting and harvest than were most of the other spiders.

A study on the effects of rain and wind on both prey and predator would help to identify positively those spider species most susceptible to these weather conditions. Preliminary data suggest that heavy rain accompanied by moderate wind gusts causes many spiders to be knocked from the plant or otherwise affected to the degree that their population is suppressed or extirpated early in the growing season. An experiment which could demonstrate which spider species are most susceptible to rain and wind would be one in which potted alfalfa, soybeans, or corn were grown in a greenhouse. These plants would then have known populations of spiders established on them. Various combinations of artificial precipitation and wind gusts could establish to what degree inclement weather conditions affect spider populations. The spiders used should be species that are abundant on at least three major crops grown in one geographical area. Additional intensive sampling should also be done in the field with natural populations. Weather equipment, including rain gauges and anemometers, should be placed in soybean fields to monitor weather data. Intensive sampling of these fields would yield ample data to correlate population data before and after rainfall.

In addition, more information is needed to determine migration and dispersal patterns of the major spider species. Data indicate that significant migration occurs to soybean fields from peripheral areas that are uncultivated and relatively undisturbed. However, some questions still must be answered concerning the importance of these areas:

1) What proportion of the total spider population in a given field disperses or balloons from a nearby area?
2) What is the composition of the flora in these nearby areas, and do certain spiders prefer certain floral hosts or combinations?
3) Would the establishment of grass or legume strips enhance the colonization of adjacent row crops by spiders and perhaps by other beneficial entomophagous insects?
4) Could spider populations in these uncultivated strips be managed to increase colonization levels in soybean fields?

One of the major factors in whether spiders could become an important part of a pest-management program is our ability to exercise some degree of control over the potential colonization of row-crop fields. If we are to acquire this ability, data indicating the major factors affecting ballooning are needed. To gather such data a four-sided, fine-mesh screen, coated with an adhesive, could be placed at varying heights at the field margin and would determine the percentage of spiders ballooning from adjacent areas, local areas, and long-distance areas. Theoretically, the larger the local migration and dispersal, the more control one could exercise over a group of spider species. Since transect samples have already indicated a rather large movement of spiders into the edges of soybean fields early in the growing season, this fact suggests that some species colonize the soybean field by short balloon trips throughout the field, and the direction of movement is probably determined by the normal prevailing winds.

Once these basic ecological factors have been established, a group of spiders could be closely studied to observe their feeding habits during the various stages of their life cycles. Isolating a single species of spider to be used in a pest-management program probably would not be successful. Using a guild of hunting spiders, each species of which prefers a somewhat different vertical location on the soybean plant and has distinctive behavioral characteristics, seems more likely to meet with success. Four or five species feeding on a variety of phytophagous insect species would undoubtedly work better than one species which might be much more selective. Also, if one or two species encountered some sort of environmental difficulty and did not survive, the remaining species could fill in the niches vacated by the extirpated species. A number of feeding studies could be made in the laboratory to answer questions about the potential impact on insect pest species:

1) What are the rates of food consumption of each member of the guild?
2) What is the feeding efficiency of each species and of the male and female of each species?
3) Are all of the major species general feeders, or do they not prey on important insect pests because of size or other factors?
4) Can these species regulate insect pest populations or contribute significantly to their regulation?

When answers to these questions have been determined, field experiments can be conducted to correlate spider abundance with the volume of insect pests they consume, and we can calculate the real impact of spiders on other arthropods under normal field conditions.

LITERATURE CITED

Bailey, C. L., and H. L. Chada. 1968. Spider populations in grain sorghums. Entomological Society of America Annals 61 (3) :567–572.

Barry, R. M. 1973. A note on the species composition of predators in Missouri soybeans. Georgia Entomological Society Journal 8:284–286.

Carner, G. R., M. Shepard, and S. G. Turnipseed. 1974. Seasonal abundance of insect pests of soybeans. Journal of Economic Entomology 67:487–493.

Chant, D. A. 1956. Predacious spiders in orchards in southeastern England. Journal of Horticultural Science 31:35–46.

Cloudsley-Thompson, J. L. 1962. Microclimates and the distribution of terrestrial arthropods. Annual Review of Entomology 7:199–222.

Deitz, L. L., J. W. Van Duyn, J. R. Bradley, Jr., R. L. Rabb, W. M. Brooks, and R. E. Stinner. 1976. A guide to the identification and biology of soybean arthropods in North Carolina. North Carolina Agricultural Experiment Station Technical Bulletin 238. 264 p.

Dondale, C. D. 1956. Annotated list of spiders (Araneae) from apple trees in Nova Scotia. Canadian Entomologist 88:697–700.

———. 1958. Note on population densities of spiders (Aranea in Nova Scotia apple orchards. Canadian Entomologist 9 111–113.

Duffey, E. 1956. Aerial dispersal in a known spider population. Journal of Animal Ecology 25:85–111.

Dumas, B. A., W. P. Boyer, and W. H. Whitcomb. 1964. Effect of various factors on surveys of predaceous insects in soybeans. Kansas Entomological Society Journal 37:192–201.

Enders, F. 1974. Vertical stratification in orb-web spider (Araneidae, Araneae) and a consideration of other method of coexistence. Ecology 55:317–328.

Fox, C. J. S., and C. D. Dondale. 1972. Annotated list of spiders (Araneae) from hayfields and their margins in Nov Scotia. Canadian Entomologist 104:1911–1915.

Howell, J. O., and R. L. Pienkowski. 1971. Spider populations in alfalfa, with notes on spider prey and effect of harvest. Journal of Economic Entomology 64 (1) :163–168.

Hurlbert, S. H. 1971. The nonconcept of species diversity: critique and alternative parameters. Ecology 52:577–586.

Leigh, T. F., and R. E. Hunter. 1969. Predacious spiders i California cotton. California Agriculture 23 (1) :4–5.

Luczak, J. 1963. Differences in the structure of communities o web spiders in one type of environment (young pine forest) Ekologia Polska, Series A, 11:159–221.

———. 1966. The distribution of wandering spiders in differen layers of the environment as a result of interspecies competition. Ekologia Polska, Series A, 14:233–244.

Mac Arthur, R. H., and E. O. Wilson. 1967. The theory o island biogeography. Princeton University Press, Princeton N.J. 203 p.

Miyashita, K. 1968. Growth and development of *Lycosa T insignita* Boes. et Str. (Araneae: Lycosidae) under differen feeding conditions. Applied Entomology and Zoology 3:81–88.

Muma, M. H. 1975. Spiders in Florida citrus groves. Florida Entomologist 58:83–90.

Neal, T. M. 1974. Predaceous arthropods in the Florida soybean agroecosystem. Master's Thesis. University of Florida, Gainesville.

Price, P. W. 1976. Colonization of crops by arthropods: nonequilibrium communities in soybean fields. Environmental Entomology 5:605–610.

———, and G. P. Waldbauer. 1975. Ecological aspects of pest management. Pages 37–73 *in* R. L. Metcalf and W. H. Luckmann, eds., Introduction to insect pest management. Wiley-Interscience, New York.

Putman, W. L. 1967. Prevalence of spiders and their importance as predators in Ontario peach orchards. Canadian Entomologist 99:160–170.

Shepard, M., G. R. Carner, and S. G. Turnipseed. 1974*a*. A comparison of three sampling methods for arthropods in soybeans. Environmental Entomology 3:227–232.

———, ———, and ———. 1974*b*. Seasonal abundance of predaceous arthropods in soybeans. Environmental Entomology 3:985–988.

Southwood, T. R. E. 1971. Ecological methods with particular reference to the study of insect populations. Chapman and Hall, London. 391 p.

Tugwell, P., E. P. Rouse, and R. G. Thompson. 1973. Insects in soybeans and a weed host (*Desmodium* sp.). Arkansas Agricultural Experiment Station Report Series 214. 18 p.

Turnbull, A. L. 1966. A population of spiders and their potential prey in an overgrazed pasture in eastern Ontario. Canadian Journal of Zoology 44:557–583.

———. 1973. Ecology of the true spiders (Araneomorphae). Annual Reveiw of Entomology 18:305–348.

Whitcomb, W. H., H. Exline, and R. C. Hunter. 1963. Spiders of the Arkansas cotton field. Entomological Society of America Annals 56:653–660.

Yeargan, K. V., and C. D. Dondale. 1974. The spider fauna of alfalfa fields in northern California. Entomological Society of America Annals 67:681–682.

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THE NEST BIOLOGY OF THE BEES

Andrena (Melandrena) regularis Malloch and *Andrena (Melandrena) carlini* Cockerell (Hymenoptera: Andrenidae)

Martha Northam Schrader Wallace E. LaBerge

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Illinois Natural History Survey
Urbana, Illinois - August, 1978

Cover Illustration.—*Andrena carlini* resting on flowers of *Dentaria laciniata* in Brownfield Woods, Urbana, Illinois (Photograp
by Joseph Laury Luth)

The Nest Biology of the Bees *Andrena (Melandrena) regularis* Malloch and *Andrena (Melandrena) carlini* Cockerell (Hymenoptera: Andrenidae)

Martha Northam Schrader and Wallace E. LaBerge

Detailed biological information on bees of the genus *Andrena* is scant and for most species nothing is known. Several valuable papers concerning *Andrena* biology are available (Davis & LaBerge 1975; Linsley 1937; Linsley & MacSwain 1956 and 1958; MacSwain 1945; Michener *et al.* 1955; Michener & Rettenmeyer 1956; Rozen 1968 and 1973; Stephen 1966*a* and 1966*b;* Thorp & Stage 1968; Youssef & Bohart 1968), and these provide us with a framework for generalizations about the natural history of the genus.

The purpose of this study is to describe the biologies of *Andrena (Melandrena) regularis* Malloch and *A. (M.) carlini* Cockerell with comparisons between the two species and between these and other members of the genus. The study began in Brownfield Woods, northeast of Urbana, Illinois, but was largely undertaken in Mohannes blueberry field, 5 miles west of St. Stephen, New Brunswick, Canada. Some data were also obtained in Busey Woods, in north Urbana, and from museum collections in the care of John K. Bouseman and Wallace E. LaBerge while a revision of the subgenus *Melandrena* was in progress. Laboratory work was done at the Illinois Natural History Survey.

Before the present study only scattered information was available regarding the biologies of *A. regularis* and *A. carlini.* Packard (1868) briefly described the burrow of *regularis* (determined as *Andrena vicina*) and outlined the temporal developmental sequence from egg to pupa. Packard (1897) also provided a brief description of the larva of *regularis* (determined as *vicina).* Atwood (1933) studied the Apoidea of Nova Scotia visiting the apple bloom and provided a short description of the nest structure of *carlini.* Boulanger *et al.* (1967) initiated studies on the native Apoidea associated with low-bush blueberries in southern New Brunswick and Maine. Both *carlini* and *regularis* were found in abundance in fields surveyed, and *regularis* was considered one of the most important native pollinators of blueberries. Some information on seasonal appearance, nesting habits, and flower relationships was given for *regularis.* Osgood (1972) noted that several species of native blueberry pollinators in Maine, including *carlini* and *regularis,* chose particular sites in which to nest, and he delineated soil and physical characteristics of areas where extensive nesting occurred. Kevan (1977, and unpublished) noted the decimating effect of Fenitrothion (an organophosphate insecticide) on wild bee populations and the subsequent reduction in blueberry yield. Kevan considered both *regularis* and *carlini* important native blueberry pollinators (among other species) adversely affected by Fenitrothion application. Lastly, Bouseman & LaBerge (unpublished) have recently revised and characterized the subgenus *Melandrena,* providing a list of the member species in the Western Hemisphere and details of their distribution and floral preferences.

Many people are to be thanked for their help with several aspects of this project. Foremost among these are William and Cole Bridges, who kindly allowed study and excavations in their blueberry fields in New Brunswick and the use of their facilities during the growing seasons of 1976 and 1977. Others whose help enhanced the quality of the work are: John K. Bouseman, Mary Fischer, Peter G. Kevan, Bruce Pendrel, Kenneth Robertson, and Donald W. Webb. Thanks are also due to George C. Steyskal of the U.S. Museum of Natural History, Washington, D.C., for his prompt identification of the anthomyiid fly found at the nest sites. We wish to thank Bernice Sweeney, Illinois Natural History Survey, for her assistance in typing, Lloyd LeMere, Survey Technical Illustrator, for designing the cover, Larry S. Farlow, Survey Technical Photographer, for aid in preparing the illustrations, and Shirley McClellan, Survey Assistant Technical Editor, for final editing.

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MATERIALS AND METHODS

Photographs were taken in 1976 with a 135 mm Minolta SR1 camera and a 55 mm Asahi Pentax camera by Peter Kevan and Bruce Pendrel, respectively. Photographs in 1977 were taken with a Nikon FT2 camera and a f2.8 Vivitar macro lens. Field

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temperatures were obtained with a shaded Celsius thermometer hanging about 1 foot from the surface of nest entrances.

In 1976 *A. regularis* burrows were marked with 3-inch brass paper fasteners and numbered consecutively as it became evident that the burrows contained actively nesting females. *A. carlini* burrows were marked randomly with brass fasteners. In 1977, *regularis* females were marked on the thorax with Aero Glass Dopa paint and fasteners were marked with the same color. The color code used was that described by Davis & LaBerge (1975). Burrows of *carlini* were marked again randomly with uncolored brass fasteners.

Burrows were poured with plaster of paris and excavated using shovel, pliers to cut through roots when necessary, camel-hair brushes, a 1–inch paint brush and a pocket knife. Burrow and cell measurements were made with a divider and a ruler in millimeters. Plastic vials were used to transport excavated cells and their contents. In 1976 larvae and eggs were stored in 70-percent ethyl alcohol. Adult females captured early in the season were stored in 70-percent alcohol prior to dissection; those captured later in the season were pinned. In 1977, eggs, larvae and females for dissection were all stored in Kahle's solution for 24 hours and then placed in 70-percent alcohol.

Pollen was obtained from burrow cells, the stomach contents of predefecating larvae, the scopa of female bees, and the forage plants themselves. In preparation for analysis, pollen was placed in glycerin jelly, stained with basic fuchsin, and mounted on slides (Thorp 1969; Davis & LaBerge 1975). Native forage plants were collected, pressed and brought back to the laboratory for determination.

For morphological studies, larvae were cleared in lactophenol, washed in distilled water and a 1-percent hydrochloric acid solution, and stained with acid fuchsin (Davis & LaBerge 1975). Measurements for line drawings were taken with an ocular micrometer of an M5 Wild dissecting microscope. The fine structure of the head capsule, mandibles and spiracles were further examined with a scanning electron microscope. Mandibles and head capsules were prepared using the critical paint method of drying. Specimens were dehydrated in an alcohol and a freon series and then placed in a Bomar SPC 900 critical paint apparatus. Following critical paint drying, specimens were mounted on aluminum plates, placed in a vacuum evaporator, and coated with carbon and a gold paladium alloy. Scanning electron micrographs were taken with a JEOL JSM-U3 scanning electron microscope by Daniel Ghiselli and Helen Sandburg at the University of Illinois.

Nests of *A. carlini* were located in Brownfield Woods, a rectangular 60-acre remnant of a forested area known as the Big Grove that once occupied a 10-square-mile area in a bend of the Salt Fork River, northeast of Urbana, Illinois. The woods is located just east of the now defunct town of Augerville and was at one time known as the Augerville Woods, a frequently recorded locality at the turn of the century. The woods is owned by the University of Illinois and is adequately described by Davis & LaBerge (1975).

The Mohannes blueberry field site (Fig. 1) of nests of both *A. carlini* and *A. regularis,* located 5 miles west of St. Stephen, New Brunswick, Canada, is owned and operated by Bridges Bros. Ltd., commercial blueberry farmers in southern New Brunswick and Maine. It is located on upland, abandoned farmland and is managed primarily by alternate burning of one-half of the field each spring (Kevan, unpublished). The field is stony with large outcrops and the topography varied, ranging from flat to gently sloping. The soil is well-drained, sandy and developed on glacial till. It consists primarily of Carlton shaly loam (gravelly loam or clay) and Georgetown gravelly sandy loam (coarse gravel deposits that occur in the form of outwashes, kanes and eskers). Such characteristics are common to the low-bush blueberry soil of Charlotte County, New Brunswick (Boulanger *et al.* 1967). The blueberry species in this field were *Vaccinium angustifolium* Art. and *V. myrtilloides* Michx.

In the following account our observations on *A. regularis* will be described first, followed by the observations on *A. carlini* and discussion and comparisons with other species of *Andrena.* As much as is possible, the account of the biology of *carlini* will be compared with that of *regularis,* so that similarities of behavior and morphology need not be repeated.

Whenever possible, each measurement is given as a mean, followed by its standard error in the conventional statistical manner.

ANDRENA (MELANDRENA) REGULARIS MALLOCH

Andrena regularis ranges throughout the Boreal and Transition Zones from western British Columbia to New Brunswick in Canada south into Pennsylvania, northern Ohio, Wisconsin and northern Minnesota in the United States. It has been collected from 6 April through 30 June and is relatively polylectic in its known floral visits (Bouseman & LaBerge unpublished).

Nest Site Characteristics

The nest site of *A. regularis* studied was located on a small, gently sloping mound about 3.1 meters from a roadside edge (Fig. 1). An aggregation of 36 nests was found within a 1.2 by 0.9 meter area with a majority of the nests clustered on the high-

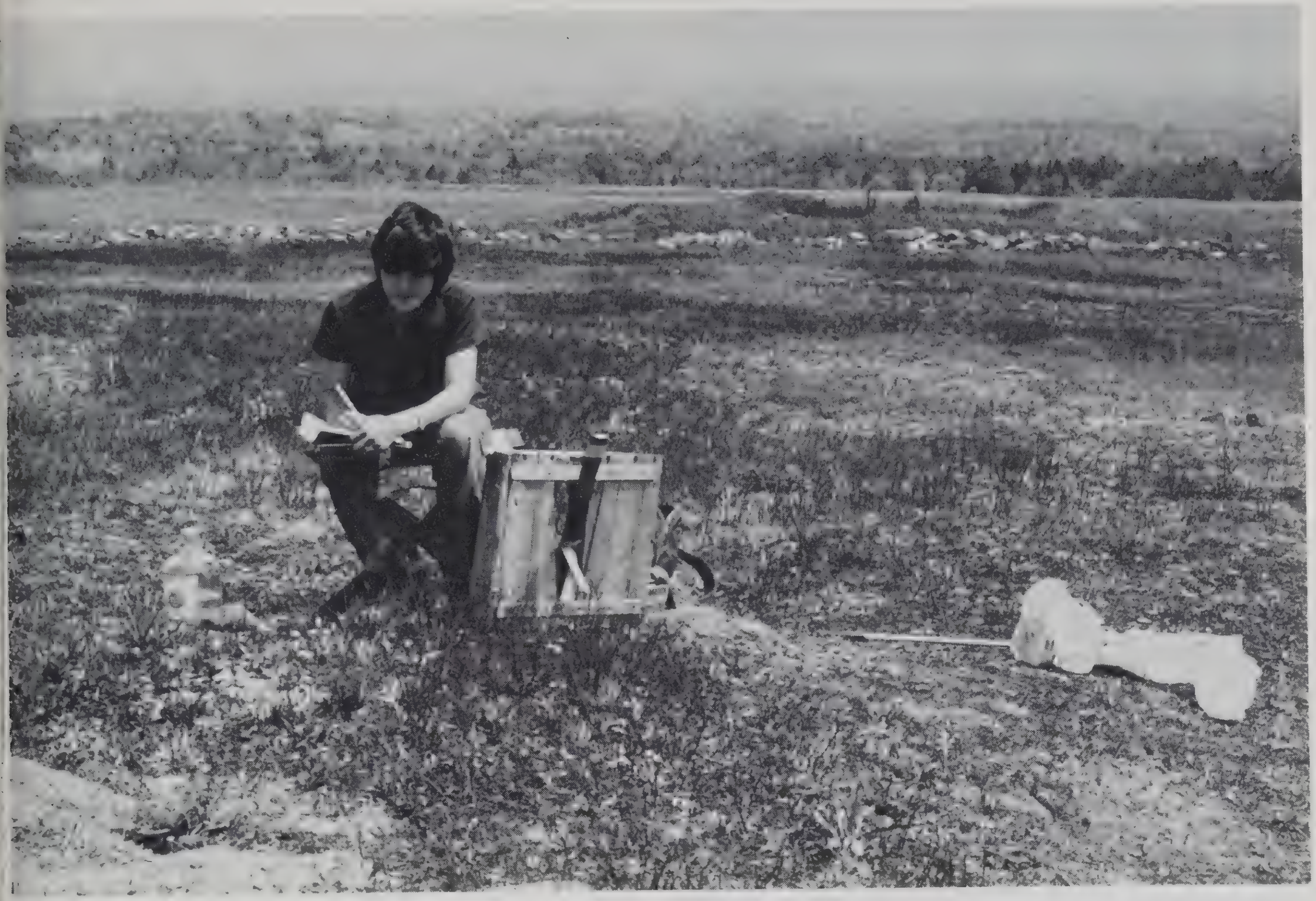

Fig. 1.—The nesting mound of *Andrena regularis* in Mohannes blueberry field, New Brunswick, in May 1976.

est portion of the mound, commonly in groups of two or three with some burrow entrances only 2.5 cm apart (Fig. 2). Additional nests were scattered along the periphery of the nesting area.

The mound was covered with burned stalks of lowbush blueberries *(Vaccinium angustifolium* and *V. myrtilloides),* lichens, some grass, leaves and twigs. Nest entrances were not obscured by the debris, but remained open and visible. The cover gradually thinned peripherally, changing from moderately dense to extremely sparse. Burrow entrances were densest in the area covered by burned *Vaccinium* stalks, with only a few entrances distributed in the sparsely covered peripheral areas. By the end of the season, here considered to be the end of the blueberry bloom and cessation of bee activity in late June, the area was covered by new blueberry shoots which appeared at the base of the burned stalks (Fig. 3 and 4).

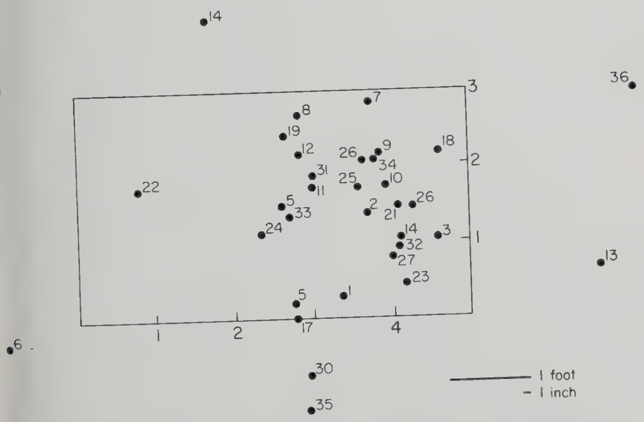

Fig. 2.—Diagram of the *Andrena regularis* nest aggregation showing locations of active burrows (1976).

Emergence, Prenesting and Mating Behavior

Upon discovery of the nest site on 26 May 1976, nesting was well under way and no prenesting activities were observed. On 12 May 1977, males and females were found crawling on the surface of the nest site. Blueberry bloom had not yet started, and closed buds were present on blueberry stalks throughout the field. Inclement weather halted bee activity from 13 May through 16 May, and burrows were excavated in order to retrieve *A. regularis* females. Specimens obtained in this manner were later dissected and found to contain sperm in the spermathecae. This indicated that copulation had occurred on or before 12 May 1977.

On 16 May a male and female were captured with a screen cone from a burrow that had been marked the previous season (Fig. 3). Both specimens

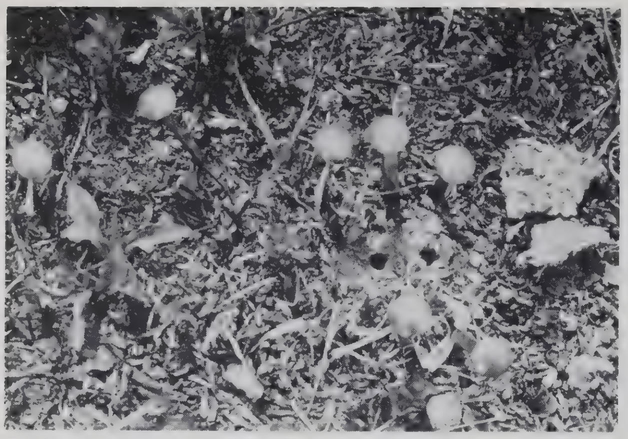

Fig. 3—Burrows of *Andrena regularis* marked with brass paper fasteners. Note the vegetation and proximity of some burrows (1976).

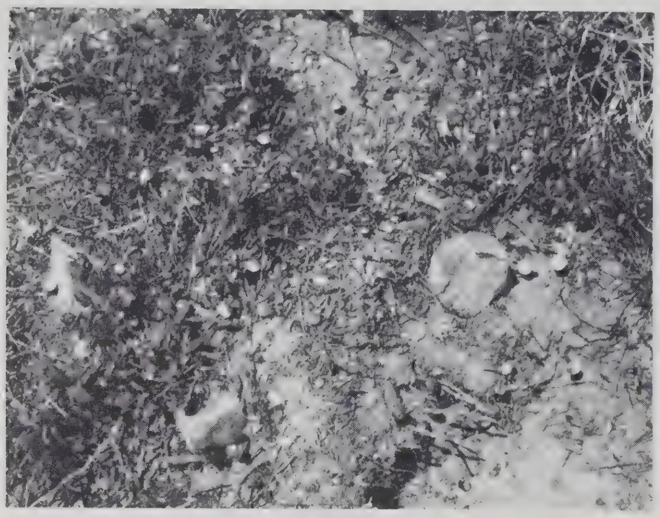

Fig. 4.—Burrows of *Andrena regularis* marked with color-coded brass paper fasteners. Note the wire cones used to capture females as they emerge from the burrows (1977).

were thought to be first emergers and the female was later found to have no sperm in her spermatheca.

Males were noted patrolling among blueberry stalks on May 16, and were also seen pollen and nectar feeding on blueberry blooms that had begun to open on 17 May. Females were also seen alighting on blooming blueberry vegetation, but no pollen collecting was observed. The females seemed to be pollen and nectar feeding, as were the males.

By 20 May the males were absent from the field and females were noted bringing pollen back to new burrows located on the nesting mound. Although more patches of blueberry were coming into bloom, the majority of plants were still in bud. Pollen sampling from females indicated that they were obtaining pollen from rosaceous plants located across the road from the blueberry field. Although dissections indicated that females had copulated as early as 12 May, and both sexes were observed patrolling blueberry stalks, copulation was not seen in the field.

Nest Architecture

Extensive excavation of *A. regularis* nests began 17 June 1976, when blueberry bloom was nearly gone and active foraging and provisioning of nests had nearly stopped. Active females in the field at this time exhibited characteristic signs of old age—confused behavior, frayed wings and loss of thoracic hair. During excavation females were often found face up in burrows, 8 to 15 cm below the surface. Females thus caught in plaster were often alive, but also exhibited signs of old age (Michener *et al.* 1955). Burrows without females in them were encountered and either were followed to the final cell (two nests) or were lost at shallow depth (ca. 10 cm). In the two nests followed to an end cell, this cell was not completely provisioned. This evidence suggests that upon completion of provisioning, the female fills in the main burrow with earth, leaving about 10 cm of the burrow open, and that the old female often remains in the 10 cm of burrow left open.

In Burrows excavated earlier in the season the deepest cell usually was incompletely provisioned. For instance, a burrow dug on 8 June 1976 contained a small larva immersed in a liquid pollen mass. The other cell at the end of the main shaft contained a small, ill-formed, irregular pellet of pollen. In other excavations, larvae in later stages of development were usually found closer to the surface than those in earlier stages or incompletely provisioned cells.

Excavation of nests in 1977 began early in the season (20–27 May). Females were captured with small wire cones placed over the burrow entrance before excavating a nest. Information was similar to that of 1976. If only one cell was found in a burrow, it was invariably located at the bottom of the main shaft and contained a roughly formed pellet of pollen and no laterals were observed. If two cells were found, the completed cell was slightly shallower in depth, was fully provisioned, contained an egg, was capped, and the burrow leading to the cell was closely packed with soil. The main shaft of the burrow was extended to a deeper level and the second cell was found at the end of this shaft. Occasionally roots and/or stones displaced the main burrow so that the second cell was located at about the same depth as the first.

Information from 1976 and 1977 indicate that *A. regularis* nests had the following characteristics (Fig. 5 and 6). Nests were 15–19 cm in depth and burrow diameter ranged from 7.5 to 9.0 mm. Main burrows were simple, unbranched and vertical to sloping at 45 degrees from the surface. Alterations in direction caused by stones and large roots were evident. Cells were often separated from such rocks only by a thin wall of earth consolidated by secretions of the female. Such secretions permeated the soil for depth of 1 mm, making it much harder than the urrounding earth. The inner surfaces of the cells ere shiny and occasionally covered by scattered drop- ets of liquid.

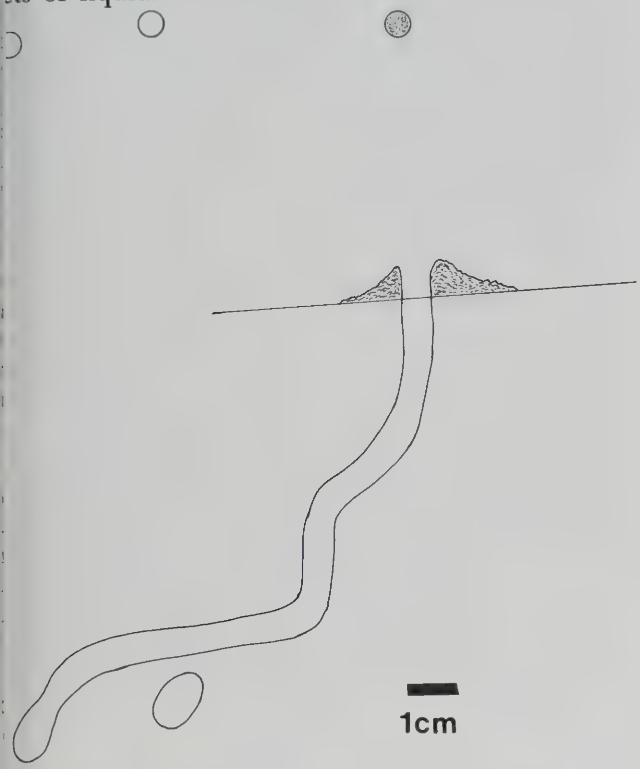

Fig. 5.—Diagram of a typical nest of *Andrena regularis* found early in the season. The open circles at the top of the figure indicate position of cells in relation to the nest entrance (the darkened circle).

Cells were found from 10–22 cm below the surface and were slanted at about 45 degrees from the vertical. Each cell was urn-shaped, averaging 14.5 ± 0.23 mm in length (N = 16), 9.0 ± 0.29 mm in width (N = 21) and 5.6 ± 0.22 mm at the narrowed neck leading to the burrow. Cells were plugged with grains of soil smoothed into the narrowed neck and arranged in a circular pattern. Four to five cells were usually found per burrow and cells were randomly placed around the main burrow. Cells were always constructed at the end of the main shaft as it was extended laterally and/or vertically. Upon cell completion 3.0–8.0 cm of the burrow was filled with soil.

Behavior at the Nest

Nest construction is probably begun soon after emergence by females of *A. regularis*. Burrows were evident on 26 May 1976 and on 12 May 1977. Burrows were located on gently sloping, well-drained areas. Digging typically began vertically on bare soil surrounded by vegetation or covered with lichens, but, where the slope of the surface was great, digging began horizontal to the surface.

On 29 May 1976, at about 1500 hours, a pollen-laden female was observed searching for a nest site and beginning a new burrow. She initially dug a shallow burrow (5–6 mm deep), then abandoned the site and began digging a short distance away. The female dug head first, breaking small, irregularly shaped pieces of earth with her mandibles. The earth was pushed backwards with the prothoracic legs, be-

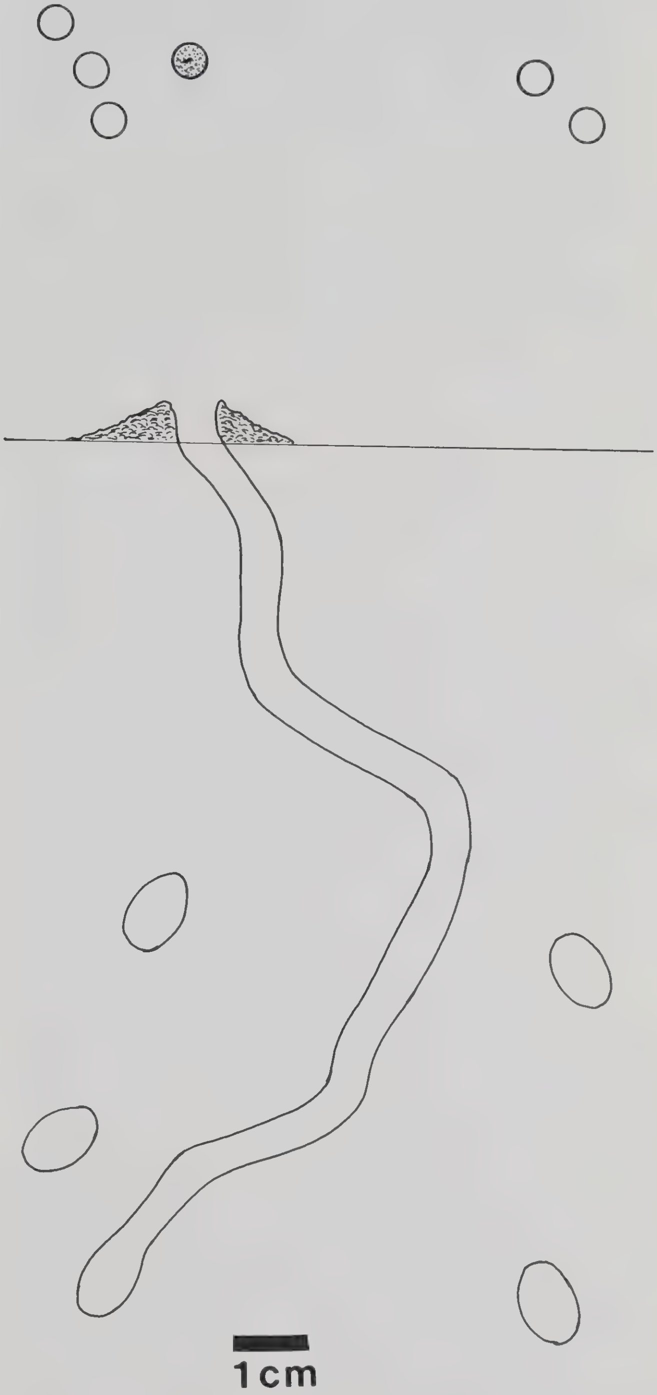

Fig. 6.—Diagram of a typical *Andrena regularis* nest found late in the season. Open circles at the top of the figure indicate positions of cells in relation to the nest entrance (darkened circle).

tween the mesothoracic and the pollen-laden, metathoracic legs. The mesothoracic and metathoracic legs were not seen to assist in either digging or pushing the earth back. As digging progressed, the female's body moved in both clockwise and counterclockwise circular motions around the perimeter of the burrow entrance. Her abdomen flicked out small pellets of earth as she dug deeper; the pygidial plate visibly pumping against the sides of the cavity. Her abdomen had completely disappeared, when the female backed out of the nest and began grooming of face and antennae with her prothoracic legs. She was disturbed by a gust of wind which blew her out of the immediate area, but she returned in a moment, relocated the excavation site and crawled into the burrow entrance. Earth was periodically heaved upward at the entrance of the burrow, some spilling out and around the entrance and some falling back into the burrow. The female at this time was entirely covered by the earth and was inside of the burrow. The heaving motion of the earthen pellets was probably due to the pushing thrusts of the abdomen and the backward action of the prothoracic legs as observed earlier.

The female had taken about 20 minutes to reach this point. She then backed out of the burrow through the loose earth, antennated the surface, hovered over the nest and did a characteristic zigzag orientation flight. She hovered over the entrance once again, landed and recommenced digging. This sequence of activity lasted about 4 minutes.

The female remained visible for about 4 minutes pushing back earth from the entrance in a clockwise-counterclockwise circular pattern until she once again disappeared beneath the soil. After about 3 minutes, the female resurfaced head first, turned around at the entrance and disappeared again, head first into the burrow. The female was not seen again that day, but on 30 May she was actively foraging and returning to the new burrow with pollen. The entrance at this time was somewhat obscured by the fresh tumulus through which the female dug.

A concentric mound of earth forms around the entrance of a burrow in the process of being excavated. This tumulus sometimes obscures the burrow entrance, but this condition seems to be temporary. The burrow entrances of *A. regularis* were found to be mostly open and quite visible. The tumuli varied in size (3.4–4.0 cm in width and 1.0–1.5 cm in height) and were often absent. Wind and rain generally obliterated tumuli soon after they were formed.

Burrows of *A. regularis* were left open during periods of daily foraging activity. After cessation of foraging, the female disappears into the burrow and may plug the entrance with particles of freshly dug soil (Fig. 7). At no time were all entrances of the burrows in the nest aggregation plugged with soil. Observations further indicated that definite trends in daily nest-plugging behavior existed. For example, plugging occurred anytime from 1100 hours to 1500 hours in the afternoon; though spot checks of the nest aggregation indicated that plugging continued well into the evening (i.e., 1945 hours). Females usually remained in the burrow and did not recommence foraging during the day in which the entrance was plugged. Females in burrows plugged early (i.e., 1100 to about 1430 hours) departed earlier for foraging on the following day than those plugging late in the day. Females leaving burrows unplugged overnight, generally began plugging activity earlier on the next day than those whose nests had been plugged the night before.

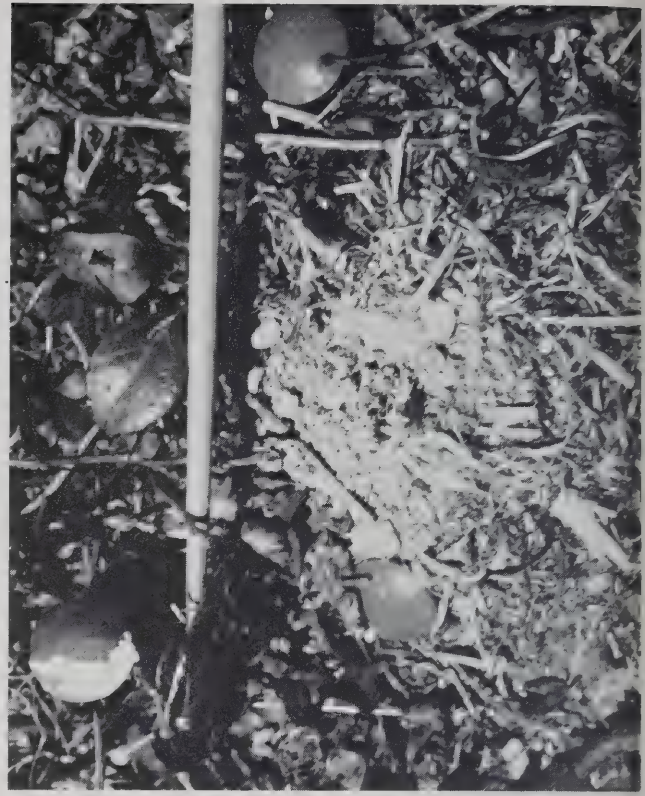

Fig. 7.—Photo of a plugged nest entrance of *Andrena regularis* (23 May 1977).

From such observations it is likely that plugging occurs when *A. regularis* has collected a volume of pollen sufficient to provision a cell. Soil pushed to the surface and plugging the entrance are due, thus, to the construction of a new cell or further burrow excavation or both. For example, on 28 May 1976, a female began plugging her nest at 1300 hours. Although activity seemed to have ceased, more soil was observed pushed toward the entrance at 1703 hours, as if the female had resumed excavation. On 29 May 1976, another female arrived at her burrow at 1232 hours and plugging was evident a few mm below the surface at 1234 hours. This entrance was observed carefully and particles of fresh earth were observed eing thrust upward in loads of varying volumes very 12–30 seconds (average 19 seconds). The longer eriods of time were followed by larger volumes of arth pushed upwards. Sixteen loads of dirt were ounted before activity ceased at 1238 hours, a total f 6 minutes. Similar observations were recorded for ther females in the aggregation.

Nests were difficult to spot in Mohannes blueberry ield because of the surrounding blueberry vegetaion and debris. Nests were located by investigators s they sat quietly and closely watched a portion of he burned field. Females were observed landing on he lip of a burrow entrance, pausing momentarily nd entering. Often no hesitation in locating the urrow was observed; females were able to fly diectly to it. Sometimes, however, a female experinced difficulty in returning to her burrow, especially f the nest entrance was obscured with debris. On June 1976, a pollen-carrying female twice attempted o locate a nest covered with earth and bits of grass. She hovered over the nest, landed near the entrance only to fly up and hover once more before flying a zigzag orientation pattern over the entire area. After anding near the nest a third time, she dug her way nto the burrow.

Similar observations were made in 1977 when females initially began foraging. Upon return from the field, pollen-laden females would perform an orientation pattern around the nest aggregation, the zigzag pattern becoming smaller until the female hovered over the burrow entrance. The hovering lasted a few seconds until the female landed near the lip of the entrance, paused momentarily and entered. Since females and their corresponding nest markers were color coded with Dopa aeroglass paint, it was further noted that females consistently entered the same burrow in the aggregation.

Females of *A. regularis* take 64.2 ± 5.64 mins. (N = 65) to make a pollen collecting trip. Pollen-laden bees entered the burrow head first and remained in the nest for an average of 30.9 ± 2.26 mins. (N = 72). While in the burrow females sometimes remained a few mm below the entrance, the head, and sometimes the head and thorax visible (Fig. 8). Sudden movement, or a shadow falling across the entrance, disturbed the female, causing her to back down into the burrow. After a few minutes, the bee reappeared at the surface and seemed to be peering at the observer. This would occur midday when females were actively foraging. Such behavior was especially noticeable when *regularis* females left the burrow for the first foraging trip of the day. The female in emerging head first often antennated the burrow wall near the entrance. One female periodically moved towards and away from the entrance, often poking head and thorax outside of the opening, for a total of 1 hour, at which time she left the burrow for her first foraging trip.

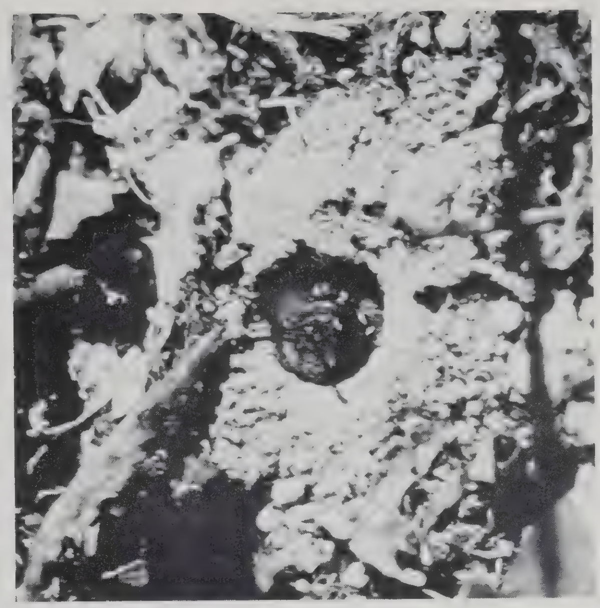

Fig. 8.—Characteristic pose of an *Andrena regularis* female at the burrow entrance before departing on a foraging trip (27 May 1977).

Orientation flights characteristically preceeded the first foraging excursion of the day. The female would crawl out of the nest, hover over the burrow for a few seconds, fly straight up and momentarily hover 10–12 cm above the burrow. She then circled the aggregation in an irregular zigzag pattern which became larger until it encompassed the entire area of nests, and she left the pattern to disappear from view. On subsequent foraging trips during the day, females rarely executed an orientation flight upon departure. If the nest entrance became obscured while the bees were foraging, nest entrances were located after some difficulty and the female executed another orientation flight upon leaving the nest.

Occasionally ants disturbed the bees. In one instance a female entered the burrow only to immediately back out and take flight. An ant was seen at the burrow entrance. Two minutes later the female returned, but was once again disturbed by the ant and departed. The ant soon left and after about 5 minutes the female returned, entered and plugged the burrow for the evening. Similarly, a pollen-laden female was chased by two ants as she attempted to return to her burrow. She hovered over the nest, almost entering, when two ants at the entrance grabbed her right foreleg. The female emitted a distinct buzzing sound, pulled away from the ants and flew away. She returned to the burrow 14 minutes later and entered without incident, but an ant was observed coming from the nest directly after the female entered.

Occasionally *A. regularis* returned to their burrows with little or no pollen. This was more common towards the end of the season, prior to 16 June. At this time activity around the nest site had diminished. Though some females were found in burrows while excavating them, most burrows had been abandoned. We believe that most females abandon their burrows after completing them. The behavior of the bees in the field at this time seemed disorientated and females flew about aimlessly, unable to locate burrows. Occasionally, bees clung to blueberry stalks or landed and walked on the ground, stopping to groom face and antennae.

Foraging and Provisioning of Cells

Much of the pollen collected by *A. regularis* in Mohannes field was that of low-bush blueberries *(Vaccinium* spp.). However, pollen found in the cells of developing larvae included that of the family Rosaceae. During the period of 20–27 May 1977, sampling indicated that *regularis* females foraged on apples *(Malus* sp.), fire cherry *(Prunus pennsylvanicus),* choke berry *(Aronia arbutifolia),* choke cherry *(Prunus virginiana),* shadbush *(Amelanchier* sp.*),* and hawthorn *(Crataegus* sp.*),* as these plants came into bloom in the vicinity of Mohannes field. Blueberry plants were not yet in bloom and *regularis* females used these other pollen sources to initiate nesting.

Incompletely provisioned cells contained a rough, spherical, ill-formed pellet of pollen (Fig. 9). Completely provisioned cells contained moist, subspherical, somewhat flattened, pollen masses to which nectar had obviously been added. The dorsal lip of the mass (relative to the cell plug) was rounded and thickened, and the center portion depressed. The overall shape of the mass resembled a thickened red-blood platelet (Fig. 10). It seemed as if the female had formed a spherical pollen mass and then flattened and molded the surface with her abdomen as she laid an egg.

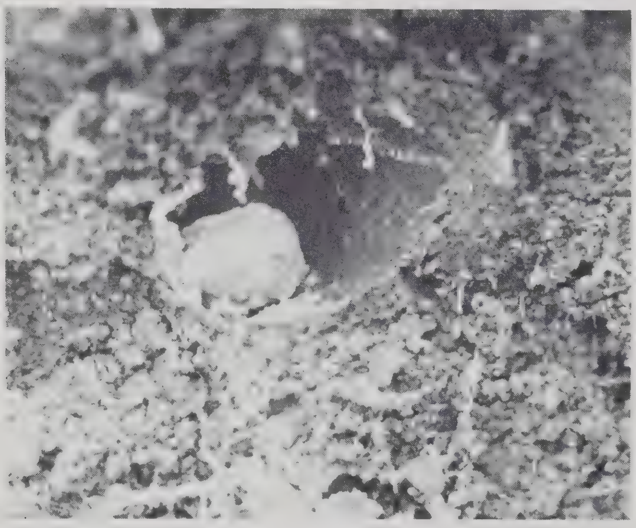

Fig. 9.—The rough, spherical, pollen pellet found in an incompletely provisioned cell of *Andrena regularis.*

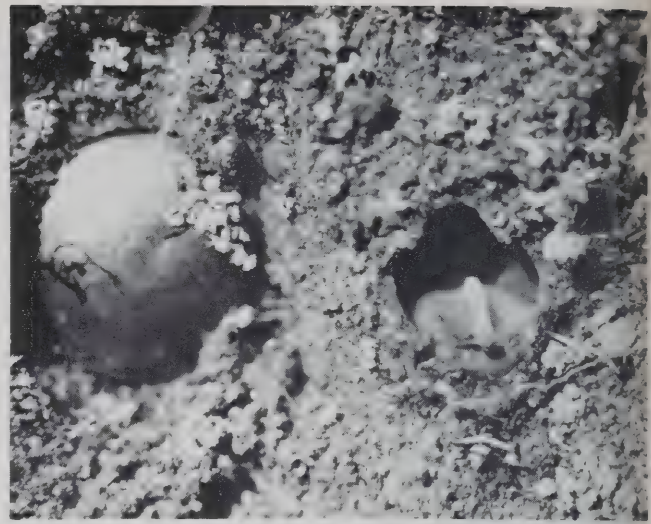

Fig. 10.—A completed cell of *Andrena regularis.* Note the somewhat depressed, flattened, pollen mass. The egg is positioned upright, one end embedded in the depressed center of the pollen mass (the sphere to the left of the cell is the head of a brass paper fastener).

In the 1976 season pollen consistency within the cells of the same burrow varied. In some cells provisions appeared liquidy, so much so that young larvae were immersed in the mass with only the dorsal portion of the body visible. In other cells pollen was dry and cakey, and a larvae removed from such a cell left indentations of its body across the pollen surface (Fig. 11). In either case, the pollen was distinctly yellow and did not change color as it was consumed by the larvae.

Females were observed leaving their burrows from 0830–1100 hours. No bees were observed bringing pollen loads back to the burrow before 0930 hours. It is likely, however, that some females began foraging before 0830 hours, as temperatures were often as high as seemed necessary for foraging. Plugging occurred from early morning to early evening and females ceased foraging for the day after plugging occurred. Many bees foraged until sunset, although some females returned and plugged burrows as early as 1100 hours and others plugged burrows between 1400 and 1800 hours. The time expended per foraging trip ranged from 23 to 272 minutes. Time spent in burrows between foraging trips ranged from 10 to 97 minutes.

Developmental Observations

In 1977 *A. regularis* began nesting in Mohannes field shortly before or on 22 May. Nests excavated from 15 May–19 May were blind burrows without cells. By 20 May females were observed returning to burrows with pollen and burrows excavated from 21 May through 27 May contained one cell with an egg. Often an incomplete cell, containing a pellet of pollen, was found at the end of the burrow. First

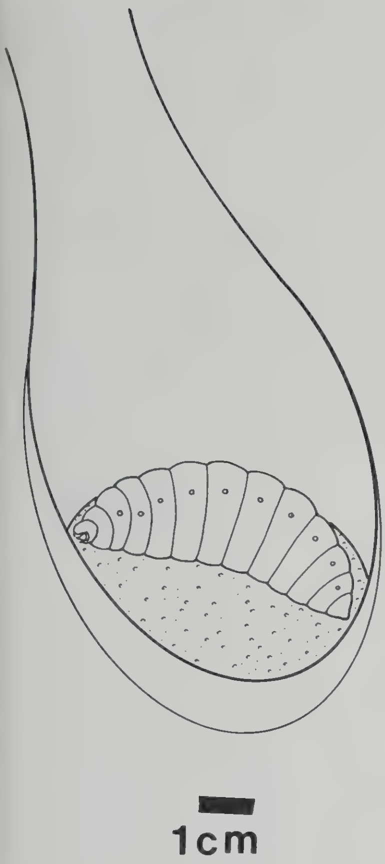

Fig. 11.—Diagram (left) showing a young larva of *Andrena regularis* positioned across a cakey, dry, pollen mass. *Andrena carlini* larvae are positioned in the same manner.

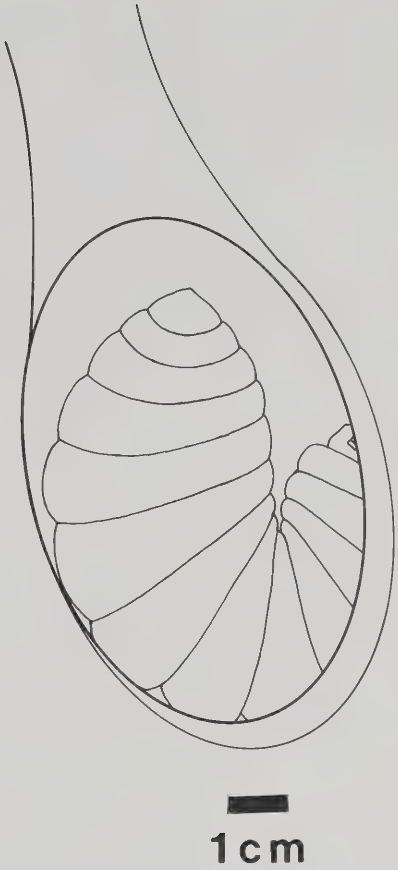

Fig. 12.—Diagram (right) of an almost mature larva of *Andrena regularis* positioned in the cell. Note the small amount of pollen at the bottom of the cell. *Andrena carlini* were found similarly positioned.

instar larvae were not found in any nest up to the time observations were terminated on 27 May 1977.

In 1976 burrows excavated from 17 June through 22 June contained larvae in various stages of development. Some larvae had consumed one-half to three-fourths of the provisions; others had consumed the provisions completely and filled the entire cell. Fieldwork terminated on 22 June 1976, and no nests were found to contain postdefecating larvae.

Larvae were found almost immersed in a liquid pollen mass in some cells. Other larvae appeared to be on the surface of a cakey pollen mass and consumed pollen directly beneath their mouthparts. Larvae encircled the pollen as they fed, until a small amount remained beneath the ventral surface of the body. Large mature larvae appeared to be positioned head down in the cell (Fig. 12).

Description and Development of the Ovary

The ovaries of *A. regularis* females differ from those of most *Andrena* now known in that they are formed into a single, fused, median organ in which six or seven ovarioles are visible. Paired lateral oviducts lead to a median genital chamber. The gonopore opens to the exterior on the posterior ventral surface of the genital chamber. Dufour's gland appears large and convoluted and shares the gonopore opening to the exterior. The spermatheca is located on the posterior dorsal surface of the genital chamber slightly posterior to the gonopore (Fig. 13).

The ovaries of two females of *A. regularis* captured at their burrows on 15 and 16 May 1977, contained follicles that were beginning to mature (Fig. 13*A* and *B*). The spermathecae of both contained sperm and the crop and midgut contained pollen. A third female was captured on 16 May 1977, from a screen cone placed over a marked nest site from the previous season. The ovary of this female was small, the follicles immature, the spermatheca contained no sperm, and the crop and midgut contained no pollen (Fig. 13*C*). The condition of this female indicated that it had just emerged, and she had not had time to feed or to copulate. A fourth female, captured on 21 May 1977, had ovaries in the condition of the first two females described above (Fig. 13*D*). On 23 May 1977, a female was captured and upon dissection was found to contain an ovary with two follicles enlarged and egglike in appearance (Fig. 13*E*), suggesting that the female was about to begin nesting.

In the 1976 season the earliest females captured and dissected were taken on 28 and 29 May. The female of 28 May had an ovary with follicles just

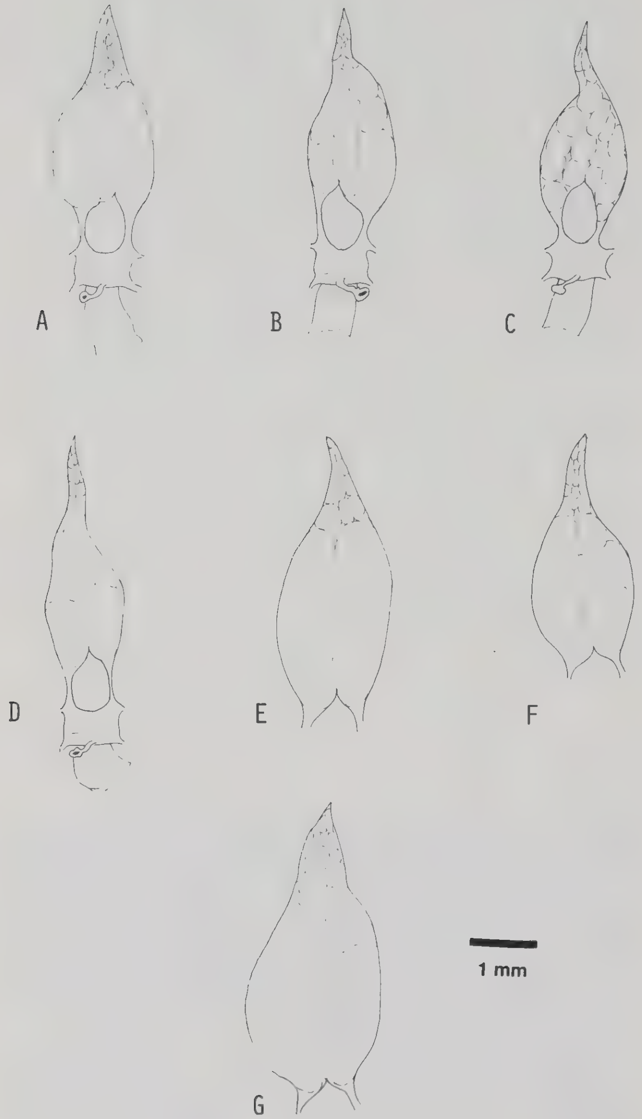

Fig. 13.—Drawings of ovaries (dorsal view) of *Andrena regularis* showing ovarian development. *A.* Female captured from burrow, 15 May 1977. *B.* Female captured from burrow, 16 May 1977. *C.* Newly emerged female taken from burrow, 16 May 1977. *D.* Female captured from burrow, 21 May 1977. *E.* Female captured from burrow, 23 May 1977. *F.* Female captured foraging, 28 May 1976. *G.* Female captured foraging, 29 May 1976.

beginning to mature (Fig. 13*F*), and the female of 29 May had enlarged, egglike follicles (Fig. 13*G*). In both cases the spermathecae contained sperm and the crop and midgut contained pollen. All females captured after 28 May had mature ovaries.

The Egg

The egg of *A. regularis* was white, slightly bowed and stood upright in the center of the pollen mass (Fig. 10). Only the distal end of the egg (relative to the cell plug) was embedded in the pollen, and it was noted that this end was slightly larger than the proximal end and rounded in shape. Eggs were 3.31 ± 0.079 mm in width (N = 6) and 9.92 ± 0.060 mm in length (N = 6).

Predefecating Larva

Body: (Fig. 14). C-shaped, about 10 mm long, 5 mm wide in lateral view; postcephalic segments 1–3 rounded in profile, segment 3 divided dorsally by distinct furrow; segments 4–10 rectangular in profile; intersegmental furrows distinct; integument smooth, lacking setae and spicules; anal opening apicomedial on terminal segment.

Head: (Fig. 14 and 15). As in *A. candida* (Youssef & Bohart 1968) except as follows: genal area with sparse setae; labrum with dense setae, thickened at

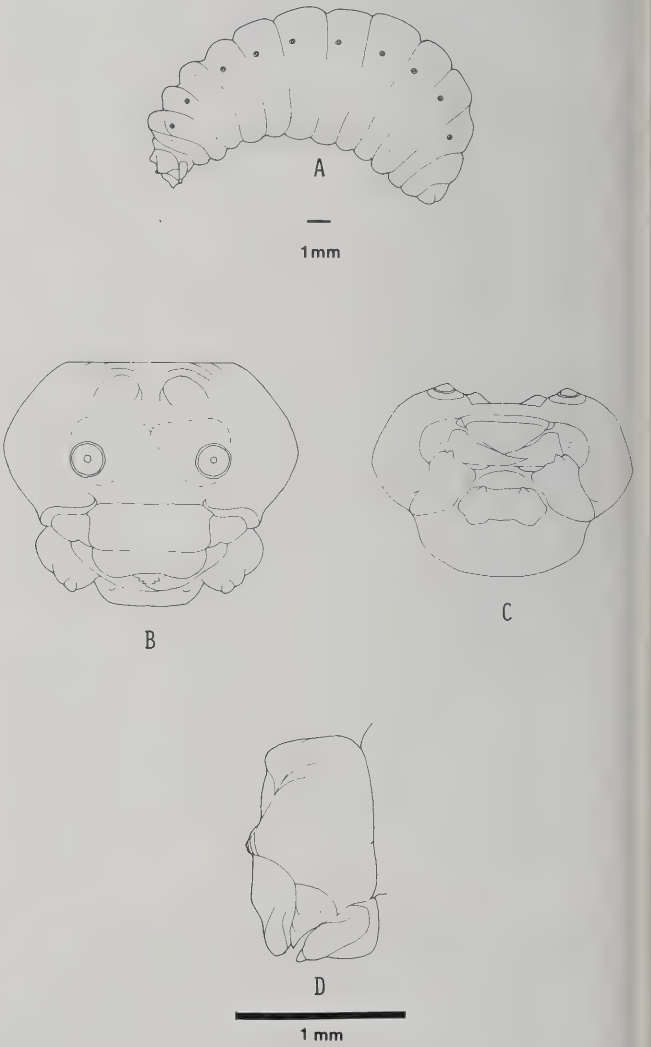

Fig. 14.—Drawings of the predefecating larva of *Andrena regularis*. *A.* Lateral view of larva. *B.* Frontal view of head capsule. *C.* Inferior view of head capsule. *D.* Lateral view of head capsule.

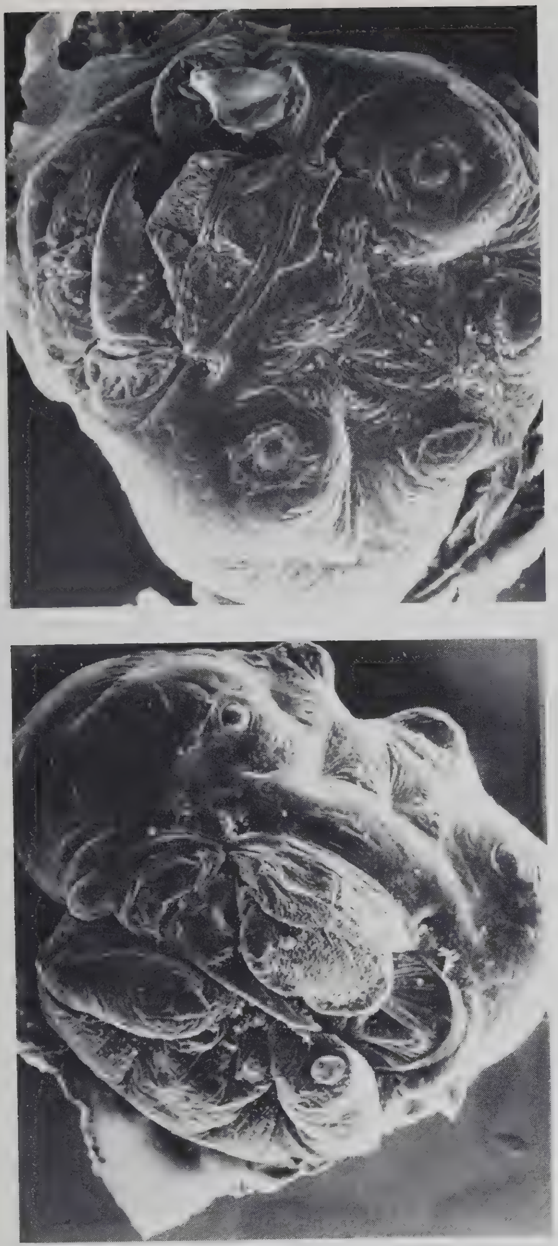

Fig. 15.—Electron microscope photos of the head of the predefecating larva of *Andrena regularis* showing the head in two views.

edge; maxillae with moderate setae; labium with sparse setae; epistomal suture distinct, cleavage line absent; mandibles (Fig. 16) with inner apical margin irregularly serrate to base of cusp, cusp with dorsal teeth ranging in size from robust to small; maxillary palpus larger than labial palpus; salivary opening on small tubercle; prementum indistinctly separated from postmentum.

Spiracles: (Fig. 17). Dorsolateral on thoracic segments 2 and 3, abdominal segments 1–8; atrium produced above body integument, discernible ridges present internally, primary atrial opening circular with collar.

Inquilines and Parasites

The anthomyiid fly, *Leucophora fusca* Huckett, sometimes followed *A. regularis* females. If followed, the bee attempted to lose the fly and flew in an irregular zigzag pattern in the vicinity of the nest site. Occasionally a female landed and rested on vegetation, and the fly would stop as well, to resume shadowing the bee when she once again took flight. On 29 May 1976, a female arrived at the nest site shadowed by a fly. The bee entered her burrow and the fly followed, but after a moment the fly backed out and positioned itself on a nearby blueberry twig head downward toward the nest entrance. At 1310 hours the bee left the nest to resume foraging. The fly immediately darted into the nest entrance, re-emerged in about 2 seconds and flew away from the site. At 1370 hours another female was observed being shadowed by a fly. The sequence of behavior was similar, although the fly remained poised on the lateral surface of a brass-tack nest marker. It was disturbed by an ant which had crawled up the marker and become disoriented. After resting for 3 minutes on the tack surface, the fly attempted to relocate the nest opening by crawling on the ground but was unable to do so. It resumed a waiting position on a blueberry stalk and, after spotting a pollen-laden female bee returning to the nest aggregation, it left the stalk and followed the bee to its burrow entrance. In this instance the fly followed the bee directly into the burrow and remained inside for 30 seconds before re-emerging and flying away.

Two anthomyiid larvae were found in a cell of an *A. regularis* burrow on 21 June 1976. One larva was slightly larger than the other (6 mm as opposed to 5 mm) and both were immersed in the liquidy mass at the bottom of the cell. A small, second instar bee larva was found in the mass as well.

On two occasions females of *Nomada imbricata* (Anthophoridae) were observed entering burrows of *A. regularis.* Unlike the anthomyiid fly, the *Nomada* females did not follow *regularis* females to their burrow. The *Nomada* patrolled the nest site, occasionally landing on blueberry vegetation. Before entering a burrow, the *Nomada* hovered over the entrance, landed, antennated the burrow rim and then disappeared into the burrow for 15–22 minutes. Upon emergence, the *Nomada* were easily captured by a vial placed over the burrow entrance.

An unidentified fly of the family Bombyliidae was commonly seen hovering about the *A. regularis* aggregation. This fly often hovered close to the ground, creating a small depression in open, unvegetated soil with the vibrating tip of its abdomen. A small, transparent egg was subsequently deposited in the depression.

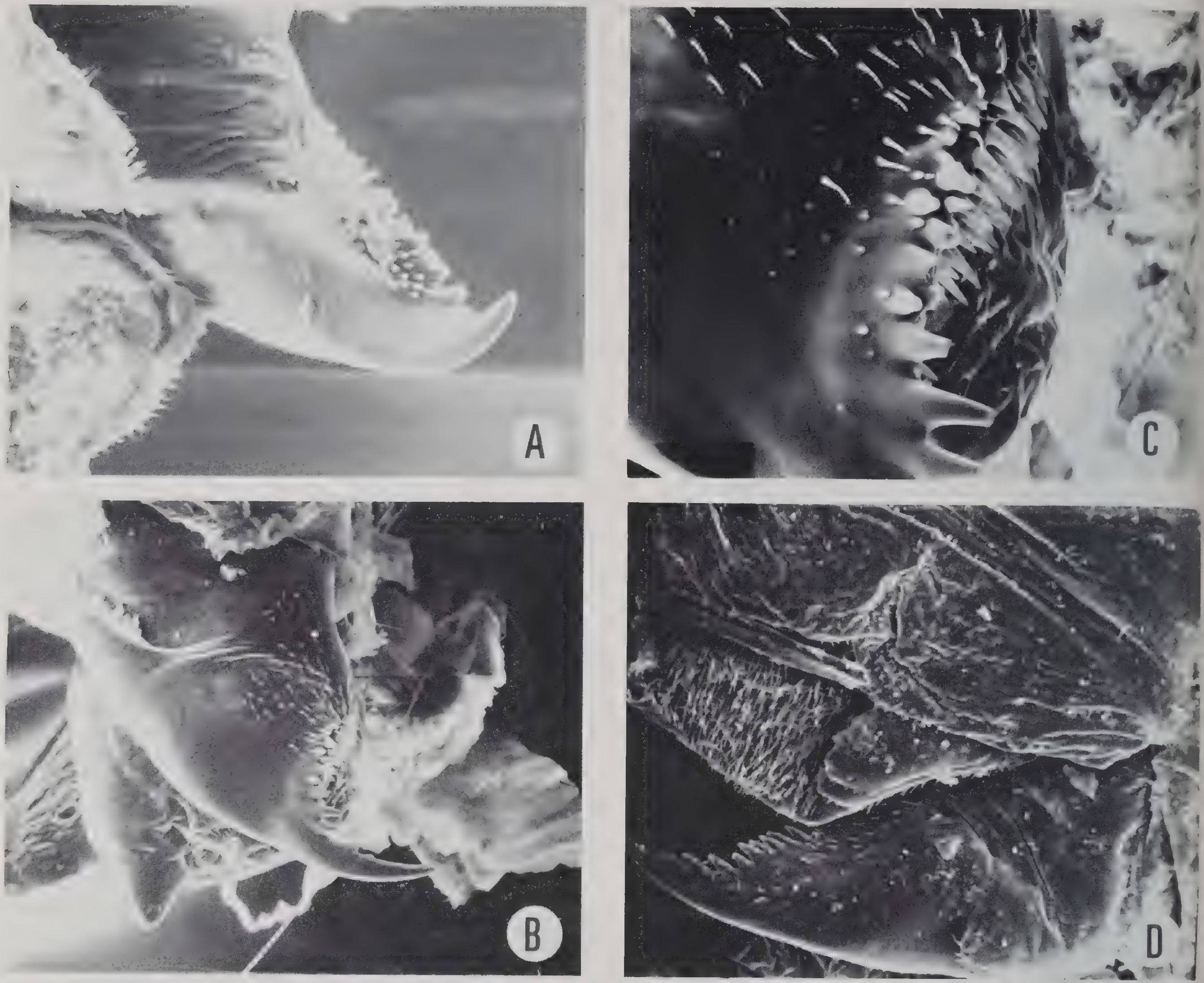

Fig. 16.—Electron scanning microscope photos of the right mandible of *Andrena regularis*. *A*. Superior surface. *B*. Outer surface showing part of the superior surface. *C*. Outer surface showing a closeup of part of the superior surface. *D*. Outer surface in relation to the labrum and clypeus.

ANDRENA (MELANDRENA) CARLINI COCKERELL

Andrena carlini ranges from Alberta and Idaho in the west to Nova Scotia and Maine in the east, and south to Georgia, Arkansas and New Mexico. It has been collected from 22 March through 26 July, but is active chiefly in April and May (Bouseman & LaBerge unpublished). It has been collected from a great many flowering plants and must be considered to be a polylectic bee.

Nest Site Characteristics

Burrows of *A. carlini* found in Brownfield Woods were located in the forest with entrances often obscured by leaves or other vegetation. Nests were isolated from one another, distances between nests ranging from a few centimeters to several meters. Female bees and their burrows were observed in Brownfield Woods for as long as 6 weeks in 1966, 1968, 1974, and 1976. Burrows were excavated several times, were found to extend vertically into the ground for 15 to 20 cm, but cells, pollen, or other signs of nesting were never found despite the fact that the females were seen entering, observed at the entrances, and taken from within the burrows.

Burrows of *A. carlini* in Mohannes blueberry field were found on elevated portions of the road and along the roadside edge (Fig. 18). Nests were isolated from one another and burrows were not usually obscured by vegetation. Some burrows were found along portions of the road covered with low grass, although entrances were easily visible. All burrows of *carlini* in Mohannes field that were excavated contained evidence of nesting activity.

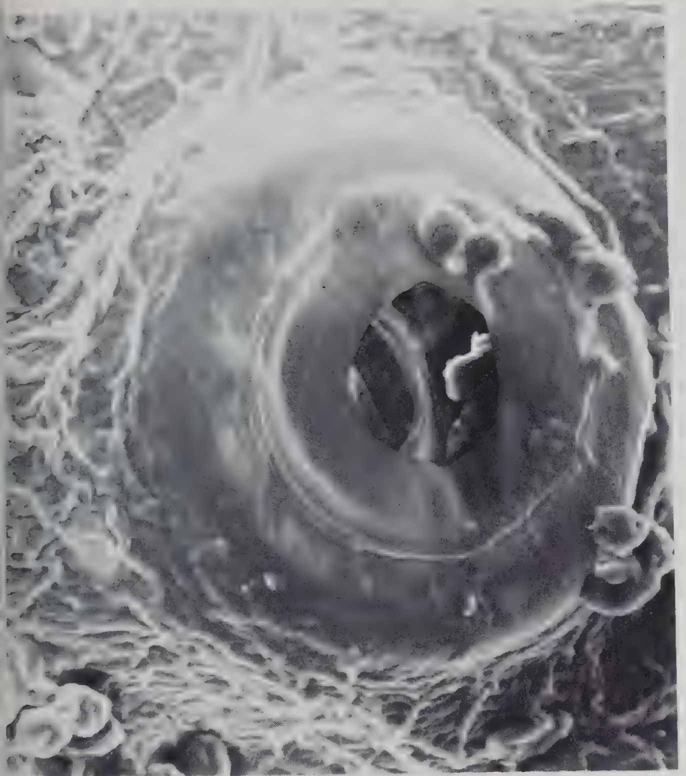

Fig. 17.—Electron scanning microscope photo of the surface of the spiracle of *Andrena regularis.*

Emergence, Prenesting and Mating Behavior

Males and females of *A. carlini* were evident foraging in Brownfield Woods, Urbana, Illinois, by 31 March 1976. Males were noted patrolling flowers *(Claytonia virginica* and *Dentaria laciniata)* probably in search of females. Females of *carlini* were not observed collecting pollen but were nectar feeding primarily from *Dentaria,* although *Claytonia* was also used. Occasionally nectar feeding was interrupted, especially in cool weather. Females would alight on leaves on the forest floor for periods of 2–3 minutes and groom themselves, often in the sunlight. After grooming, patrolling and nectar feeding would recommence. The females were strong fliers and difficult to follow, but they seemed to slow down between 1500 and 1700 hours and this is the period during which most burrows were discovered.

Foraging females of *A. carlini* were observed stripping pollen from anthers of trout lily *(Erythronium* sp.) in Brownfield Woods on 6 April 1976. An attempt was made to follow pollen-laden females to their burrows without success. Most females continued to nectar feed and pollenless females returned to burrows in the leaf litter under the forest canopy. On 3 April 1976, one female entered a burrow in the leaf litter with some pollen on her hind legs. This burrow was later excavated and proved to be

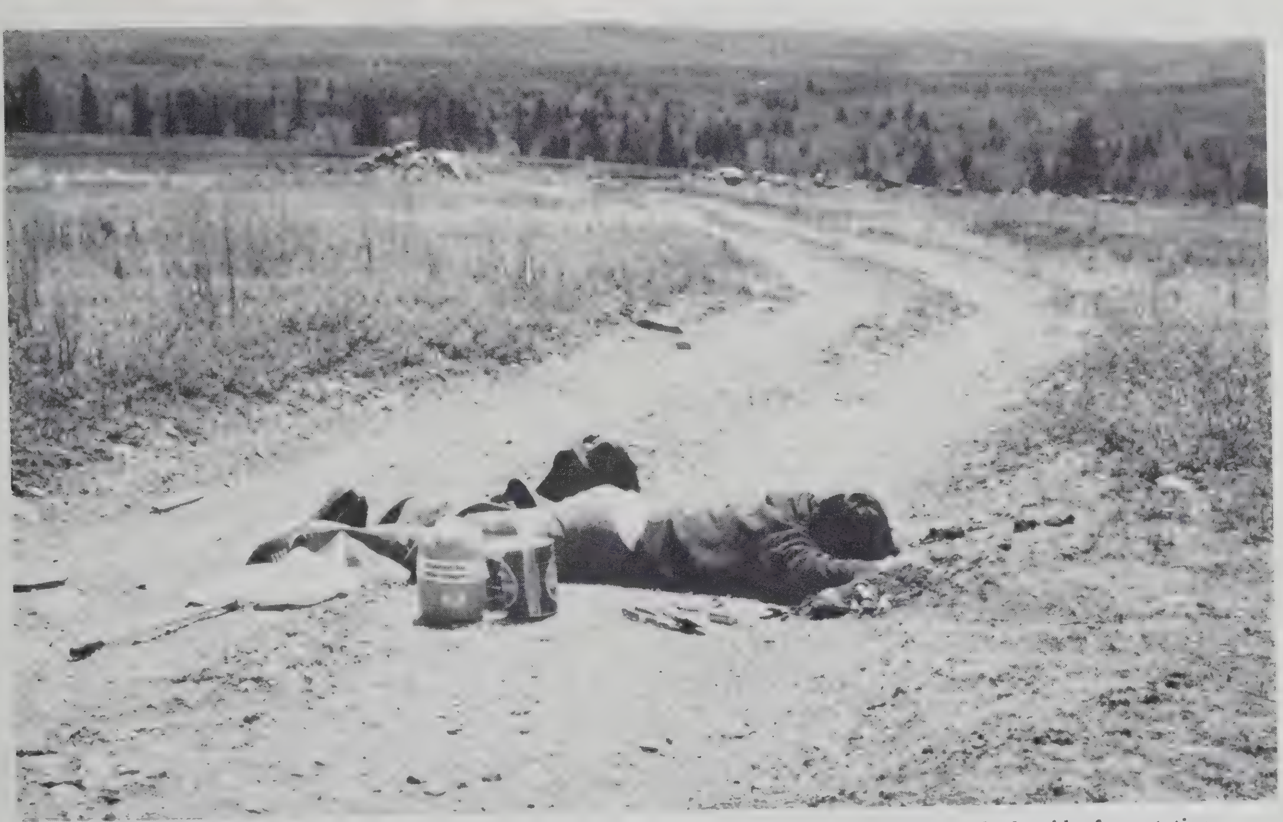

Fig. 18.—Excavating a burrow of *Andrena carlini* in May, 1977. Note the burrow is on a road, devoid of vegetation.

sterile, as were all of the burrows found in the woods. By 30 April most activity in the woods had ceased; *carlini* was rarely seen. Search of nearby areas of hard-packed soil outside of the forest canopy did not result in the discovery of any *carlini* burrows.

Males of *A. carlini* were observed nectar feeding from *Dentaria laciniata* on 30 March 1977, in Busey Woods, Urbana. On 2 April females were noted in Busey Woods and a copulating pair was observed on an open blossom of trout lily *(Erythronium* sp.*)*. The male was positioned on top of the female with his copulatory organs placed in the female's genital opening. The pair was captured and placed in a vial where it was observed that the male had some difficulty in disengaging. Bouseman (personal communication) observed similar activity in Brownfield Woods on several occasions in the spring of 1971. On 12 April 1971, males were observed patrolling flowers of bloodroot *(Sanguinaria* sp.*)*. Three pairs of *carlini* were observed mating on open flowers. In one case an attempted copulation was disrupted by the landing of a second male on the back of the male attempting to insert his copulatory organs into the female genital opening. On 15 April 1971, several copulatory attempts were observed but none were successful.

In Mohannes field, New Brunswick, two females were captured and dissected on 15 May 1977. Both females had sperm in their spermathecae, indicating that copulation had occurred. Males were observed patrolling blueberry stalks from 15 May through 20 May, occasionally feeding on freshly opened blueberry flowers. Similar behavior was observed for females, but by 18 May some females were observed collecting pollen on nearby strawberry bloom *(Fragaria* sp.*)*. By 20 May, the males had disappeared from the field and females were actively bringing pollen to burrows. Sampling indicated that *carlini* females were obtaining pollen from *Fragaria virginiana, Prunus pennsylvanicus, P. virginiana, Malus* sp., *Aronia arbutifolia Crataegus* sp., and *Amelanchier* sp., all rosaceous plants, located across the road from the blueberry field. This was at a time when most of the blueberry plants were not yet in bloom.

Nest Architecture

Nest construction probably began soon after emergence of *A. carlini*. Digging behavior was not observed and it is not known whether *carlini* plugs the nest entrance with earth pellets after foraging is completed for the day as does *A. regularis*. In 1976 nests of *carlini* were excavated from 8 June through 22 June. A burrow dug on 8 June had eggs and second and third instar in cells at depths of 14.5–17.5 cm. The cell at the end of the main burrow shaft had not been provisioned. In another burrow larvae were found at depths of 16–20 cm, while the cell at the end of the shaft was unprovisioned.

In burrows dug near the end of the blueberry season (12 June through 22 June 1976), females were found face upwards in the burrows at a depth of 10 cm. Burrows were lost below this depth, suggesting that at the completion of the last cell the burrow had been plugged to a distance of about 10 cm from the surface.

Burrows of *A. carlini* were excavated early in the season in 1977 (20–27 May) at the onset of active foraging activity. If one cell was found in the burrow, it was invariably located at the end of the main shaft and contained a roughly formed pellet of pollen. If two or three cells were found, the completed cells were slightly shallower in depth, contained pollen and eggs and were capped. The portion of the burrow leading to the completed cells was filled with closely packed soil. A cell at the end of the main shaft (seemingly extended after the last cell was completed), usually slightly deeper than the completed cells, contained incomplete pollen balls or nothing at all.

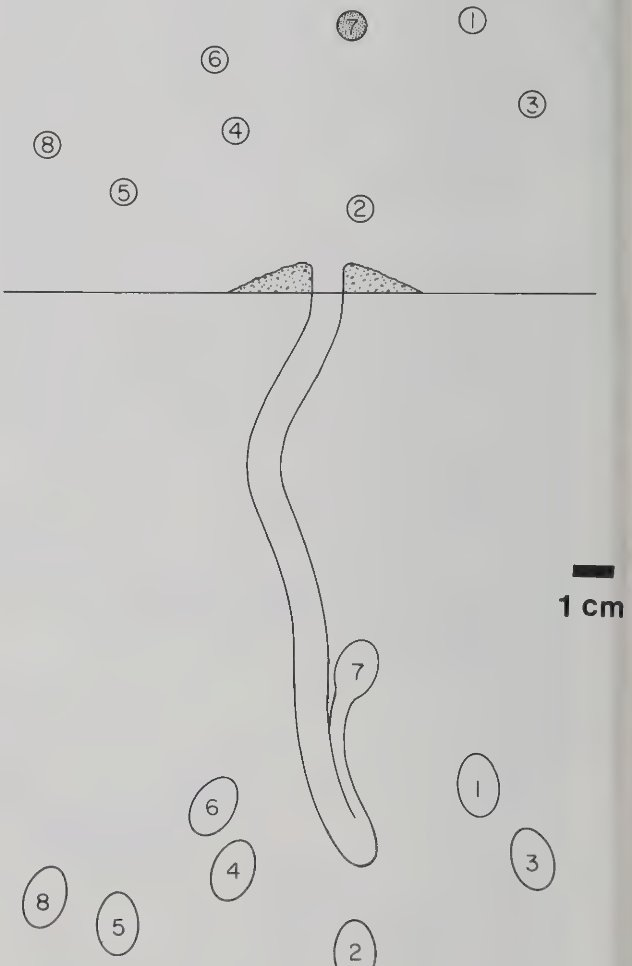

Fig. 19.—Diagram of an *Andrena carlini* burrow dug in 1976. The cells are numbered in the order of discovery. Open circles at the top of the figure indicate the random arrangement of cells in relation to the nest entrance (darkened circle).

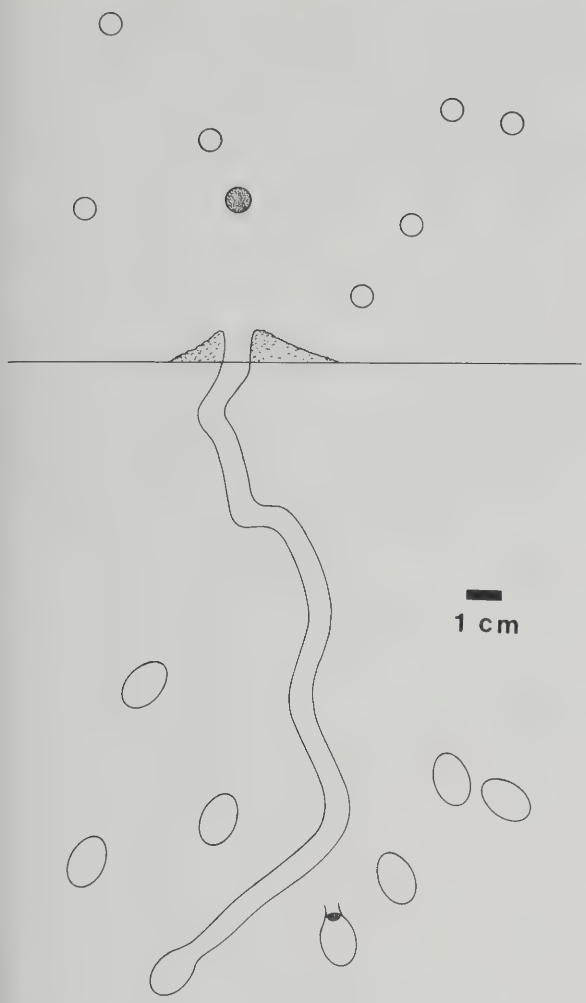

Fig. 20.—Diagram of a nest of *Andrena carlini* with the arrangement of cells indicated by open circles and the nest entrance by a darkened circle at the top of the figure (1977).

Information from both 1976 and 1977 are grouped together in the following nest descriptions (Fig. 19 and 20). Tumuli surrounded most nest entrances and ranged from 3 to 5 cm in width and 0.5–1.0 cm in height. Burrow shafts were 14–23 cm in depth, and diameters ranged from 7.5 to 9.0 mm. Main burrow shafts were simple, unbranched and vertical on flat surfaces. Along road banks, however, burrows were initially constructed horizontally before extending vertically downward. Shafts often curved to avoid obstacles. In one nest, the burrow made a sharp right angle at 15.5 cm depth, and extended slightly upward ending in a cell at a depth of 14.5 cm. Other cells of this burrow were found at depths up to 17.5 cm (Fig. 19). However, burrows usually extended vertically into the earth, ending in a single incompletely provisioned cell which was the deepest cell of that burrow (Fig. 20).

Five to eight cells were found per burrow, although one nest had only three cells. The cell wall was consolidated and the inner surface polished as in *regularis.* Cell plugs in completed cells were as described for *regularis.* Cells were found to occur from 13.5–26.0 cm in depth and ranged in position from vertical to nearly horizontal. The majority of cells were slanted downward from the burrow at an angle of 45 degrees from the horizontal. Cells were urn-shaped, averaging 14.1 ± 0.40 mm in length ($N = 15$), 9.4 ± 0.23 mm in greatest width ($N = 16$) and 5.8 ± 0.66 mm ($N = 9$) at the narrow neck.

Behavior at the Nest

Observations of *A. carlini* behavior in Mohannes field, New Brunswick, were not as extensive as those on *A. regularis.* On one occasion, however, it was noted that the female was able to locate, land on the lip and enter the burrow without an orientation flight.

On 6 April 1976, in Brownfield Woods, Urbana, Illinois, an *A. carlini* female was observed upon returning to a burrow to land upon a dry leaf, fly up and hover over the leaf, land on the leaf a second time, and then disappear beneath the leaf. When the leaf was removed, a burrow entrance was uncovered. In some instances in Brownfield Woods, when the burrow entrances were not obscured by leaves, the females seemed able to fly directly to the entrance.

Behavior of *A. carlini* at their nests was not observed in Mohannes field, New Brunswick. In 1976 in Brownfield Woods it was observed that females would occasionally remain in burrows, head up, a centimeter or so below the surface. They would occasionally move up to the burrow rim, antennate the surface and move back down when startled by movement of the observer or a shadow. Upon leaving the burrows, females crawled out to the narrow rim, antennated the surface, emerged and hovered over the burrow entrance, and executed an orientation flight over the area. Overcast, cool weather seemed to reduce activity of foraging females of *carlini* both in Brownfield Woods and in Mohannes field, but did not stop it altogether.

Foraging and Provisioning of Cells

In completely provisioned cells of *A. carlini* nests contained rough, spherical, ill-formed pellets of pollen. Completed cells contained moist, flattened, spherical pollen masses to which nectar had been added and they were very similar to those of *regularis.* In the season of 1976, pollen consistency within completed cells of the same burrow varied. Larvae were sometimes immersed in a liquid mass, and at other times lay on the surface of a pollen mass of cakey texture. No data were obtained concerning foraging time of *carlini.*

Developmental Observations

In 1977 *A. carlini* in the Mohannes field began nesting activities just before or on 21 May. Nests excavated on 15 May and 18 May were blind burrows, without completed or partially completed cells present, and resembled the burrows of *carlini* found in Brownfield Woods, Urbana. Females were observed returning to burrows laden with pollen on 21 May and burrows excavated from 21 May through 27 May contained two to three cells with eggs. Only one incomplete cell was found per burrow, characteristically at the end of the main shaft and usually containing a rough, unfinished pellet of pollen. Field observations of *carlini* were terminated on 27 May and first instar larvae were not yet present in any cell.

In 1976 burrows excavated in Mohannes field from 8 June through 22 June contained eggs and larvae in various stages of development. One burrow dug on 8 June contained eggs as well as a larva that had consumed about one-fourth of its provisions. A burrow excavated on 14 June contained eggs, larvae that had consumed very little provisions and a relatively large larva which had consumed nearly all of its provisions. On 16 June a burrow contained three larvae which had eaten one-half to three-fourths of their provisions. On 22 June a burrow contained eggs as well as larvae in early stages of development.

Feeding larvae were positioned as described for *A. regularis* and this depended, as in *regularis,* upon whether the provisions were semiliquid or cakey. Large, mature larvae appeared to lie positioned head downward in the cell, as in *regularis.*

Description and Development of the Ovary

The ovaries of nesting *A. carlini* are fused medially and in all details are like those of *A. regularis* described above. Females captured in the spring of 1977 in Busey Woods and Brownfield Woods were dissected to ascertain ovary development. On 2 April, a female from Busey Woods had small, immature ovaries, although the spermatheca contained sperm and the crop and midgut were filled with pollen. Two females captured on 15 April from Busey and Brownfield Woods, respectively, had ovaries in which the follicles were mature. In particular, the female from Busey Woods appeared ready to lay eggs. Both females had sperm in their spermathecae and pollen in their crops and midguts.

In Mohannes field in 1977 several females were captured to study ovarian development (Fig. 21). Before 18 May the ovaries showed little sign of development, but on that date one female seemed about ready to lay eggs, with follicles fully expanded. No female was taken, before or after 18 May, which had not copulated, as evidenced by sperm in their spermathecae. All females captured in Mohannes field after 28 May had mature ovaries and sperm in their spermathecae.

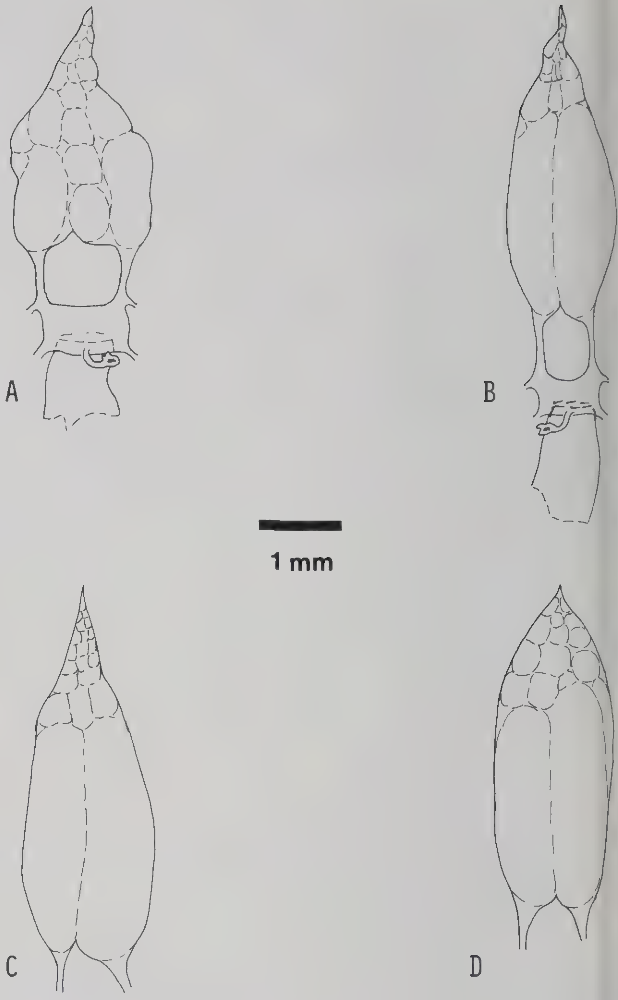

Fig. 21.—Drawings of ovaries of *Andrena carlini* captured while foraging in Mohannes blueberry field, New Brunswick. *A.* 15 May 1977. *B.* 17 May 1977. *C.* 18 May 1977. *D.* 26 May 1976.

The Egg

The egg of *A. carlini* was like that of *A. regularis* in all respects of shape and positioning in the cell. Eggs of *carlini* averaged 3.10 ± 0.062 mm in length (N = 7) and 0.90 ± 0.035 mm in width (N = 7).

Predefecating Larva

No predefecating larvae of *A. carlini* were found, since none of the larvae excavated had completely consumed all of its provisions.

Inquilines and Parasites

Although *A. carlini* were not observed closely enough to note behavioral interaction between female bees and anthomyiid flies, two anthomyiid fly larvae were found in one *carlini* brood cell on 11 June 1976. One larva was slightly larger than the other (6 mm as opposed to 5 mm) and both were covered by the liquid pollen mass at the bottom of the cell. A small, second instar, bee larva was found in this cell as well.

An unidentified species of *Nomada* was noted hovering around the sterile burrows of *A. carlini* in Brownfield Woods in April of 1976. On one occasion a *Nomada* female entered one of the woodland burrows for a few seconds. No *Nomada* were observed at the burrows of *A. carlini* in Mohannes field, New Brunswick.

DISCUSSION AND COMPARISON

Range

The range of *A. regularis* seems to be restricted to the Boreal or nearby Transition Zone, whereas that of *A. carlini* extends much further south in the Appalachians and even into the tall grass prairie regions. Although *regularis* and *carlini* are both clearly polylectic in flower preferences, *carlini* is far more so than *regularis* (Bouseman & LaBerge unpublished). It may be that the ability to use more pollen sources allows *carlini* to extend its range far beyond that of *regularis* which seems to be somewhat tied to ericaceous plants of the boreal regions. Furthermore, the nesting habits of *carlini* (nonaggregative in hard-packed soil), together with its ability to use many sources of pollen, may have allowed it to extend its range in relatively recent times due to the changes in environment by the action of civilization.

Nest Sites

In both localities (New Brunswick and Illinois) *A. carlini* seemed to be nongregarious, whereas *A. regularis* seemed to be a gregarious-nesting bee. It is not clear why some *Andrena* nest in aggregations while others are solitary. Perkins (1919) stated that some *Andrena* (notably *trimmerana, nitida* and *albicans*) never formed nesting colonies, while others *(A. cineraria)* will form dense colonies at one locality and at other localities will be scattered singly or in groups of two or three. Hirashima (1962) reported that burrows of *A. knuthi* were densely distributed in vegetated areas and sparsely distributed in bare ground. Nest scattering may be due to the fact that an entire area is suitable for nesting and aggregation due to the localized state of suitable sites. Although *carlini* is here considered to be more or less solitary, the roadbed site of Mohannes field did restrict the nests of *carlini* in a more or less linear series, although the nests were not closely aggregated. Nest scattering may also be the result of intense predation and/or parasite pressure. Presumably the more scattered the nests, the less likely they will all be located by parasites.

Osgood (1972) delineated characteristics common to areas within blueberry fields having good populations of nesting bees. The majority of nesting occurred at the highest point in a field or on a southwest slope. Plant cover was intermediate to sparse and the surface had good surface flow and drainage. Soil analyses indicated that wild bees nested in the greatest number where the O_2 horizon was loose and pliable with low organic carbon content. These characteristics generally fit the nesting site of *A. regularis* in Mohannes field, but not that of *A. carlini.*

Interspecific competition may account for the fact that nest sites of *carlini* and *regularis* were distinctly separated in Mohannes blueberry field. Since these are two closely related species (both in the subgenus *Melandrena*), using the same available pollen sources (notably cherry, apple and blueberry pollen), some type of competitive exclusion can be expected. Linsley *et al.* (1955) reported that under favorable conditions (an abundant pollen source, good weather conditions) three species of *Andrena* of the subgenus *Onagrandrena (mojavensis, oenotherae* and *deserticola)* shared the same available resources by differential nest site selection as well as slight differences in daily and diurnal pattern of activity. It is plausible that *regularis* and *carlini* co-exist in the same manner.

A final factor influencing nest site location in New Brunswick, not common to most species of *Andrena,* is burning; the common blueberry field management procedure practiced in early spring (strip-burning, rather than burning of entire fields). Burning serves a threefold purpose: it prunes and renews the blueberry plants, thereby increasing the yield and quality of fruit in the following year; it checks certain types of fungus diseases and pests that attack the plants (Phipps 1930) ; and it halts the encroachment of the surrounding forest (Kevan, unpublished). Furthermore, Boulanger *et al.* (1967) reported that this practice resulted in an increase in the number of native bees. Boulanger *et al.* (1967) were under the impression that *A. regularis* preferred the vegetative cover of unburned portions of the field. The present study shows that *regularis* may nest actively in burned portions of blueberry fields. Slope and drainage or soil characteristics may be more important than burning and the relative importance of these various factors on nest site selection is unclear.

In contrast, *A. carlini* seems to be a species which nests in sites devoid of both burned and unburned vegetation and the overall effect of burning in blueberry fields is probably minimal. The burrows of *carlini* found scattered in the leaf litter of Brownfield Woods near Urbana, Illinois, do not appear to be true nests but are probably refugia constructed by newly emerged females before nesting. Why some of these burrows seem to be occupied for as much as 30 days or more is unexplained. However, no marking studies have yet been done to show that a burrow is occupied by only one female and not by two or more in consecutive order.

Emergence and Mating

Boulanger *et al.* (1967) reported that native blueberry pollinators, especially the larger species of *Andrena,* made their appearance shortly before the blueberry blossoms. This is supported by observations made in Mohannes field in 1977; females and males of both species were observed on 12 May, 5 days before blossoms were found on blueberry plants. Furthermore, both *A. carlini* and *A. regularis* used other sources of pollen to initiate nesting before blueberries were in peak bloom.

Peak emergence dates for *A. regularis* in Mohannes blueberry field were 12 May for males and 18 May for females; strong evidence for proterandry (Boulanger *et al.* 1967). Peak emergence dates are not available for *A. carlini,* but collection records (Bouseman & LaBerge unpublished) indicate that males of both *carlini* and *regularis* emerge prior to the females. This is consistent with observations of *carlini* recorded in Brownfield and Busey Woods in Urbana, Illinois.

Copulatory behavior was observed for *A. carlini* in Illinois but has not yet been observed for *A. regularis.* Mating behavior is similar in the two species, occurring on flowers where both males and females are foraging shortly after emergence and where males are patrolling actively, probably seeking females.

Data regarding male longevity is meager, but evidence suggests that males of both *A. carlini* and *A. regularis* patrol vegetation for a week or more following emergence. Copulatory activity was recorded in Illinois for *carlini* as early as 2 April and as late as 15 April, allowing at least 13 days for patrolling behavior of males. In New Brunswick, *regularis* males had their peak emergence 12 May and were seen until 20 May, allowing at least 8 days or more for activity. Stephen (1966*a*) reported that males of *A. viburnella* patrolled the nesting site for 10–12 days following emergence. Michener & Retttenmeyer (1956) reported that males of *A. erythronii* marked between 9 and 16 March were still seen as late as 25 March.

Both *A. carlini* and *A. regularis* in Mohannes field presumably mate soon after emergence. All females captured and dissected from 12 May to 27 May had sperm in their spermathecae and the only female taken that did not have sperm was collected in a wire cone placed over an unopened nest of the previous season. Females of both species spend some time visiting flowers of rosaceous plants and blueberries in Mohannes field prior to nesting. Presumably this is the period of ovary maturation and pollen feeding is probably necessary for this to occur. The females of both *carlini* and *regularis* can be found in blind burrows in Mohannes field prior to 20 May. It is not clear whether these burrows become nests after ovary maturation is complete or whether new burrows are dug. In Brownfield Woods, Urbana, Illinois, blind burrows of *carlini* early in the season do not become nests later in the season, so far as we have been able to determine. The bees in Brownfield Woods presumably use the flowers of the forest floor for early foraging before nesting begins, and the burrows dug in the woods are assumed to be temporary refugia for these bees.

Nest Architecture

Nest structure is essentially identical in *A. carlini* and *A. regularis,* although nest site differed somewhat. Cells of both are coated with a highly polished, consolidated, internal surface characteristic of all *Andrena* species thus far studied. Thorp (1969) reported that the internal cell coat in *A. chalybaea* consisted of waterproof material. Rozen (1968) reported the same for *Melitturgula briensi* Friese (Andrenidae: Panurginae). Davis & LaBerge (1975) reported the shiny inside coating of cells to be waterproof in *A. erigeniae.* It is probably waterproofing in both *carlini* and *regularis* as well, but the nature of the substance impregnating the soil to form this layer remains undetermined.

Observations indicated that *A. carlini* burrows average slightly deeper than *A. regularis* burrows, and that *carlini* produces slightly more cells per burrow than does *regularis* on an average. The form of the burrows and the shape and size of the cells of the two species are very similar. New cells in both *carlini* and *regularis* are always found at the end of the main burrow shaft. A portion of the burrow next to a newly completed cell is filled with earth and the main burrow shaft extended in a slightly different direction and usually to a deeper level. Thus, no true laterals to the cells exist, but the so-called laterals (now filled with earth) to the completed cells are really parts of the main burrow shaft of the nest at an earlier stage of construction. This type of construction must represent only a slight evolutionary advance from those bees which construct a simple burrow with a single cell at the bottom. Likewise this seems to be a more primitive construction method than that of those bees which dig a deep burrow and then dig laterals, either regressively or progressively, to cells but retain the original deep burrow without a cell. Digging behavior of *A. carlini* was not observed, but was presumably the same as for *A. regularis* in Mohannes and essentially the same as that described for other *Andrena.* Davis & LaBerge (1975) and Michener & Rettenmeyer (1956) describe similar sequences of behavior for *A. erigeniae* and *A. erythronii,* respectively.

Nest-plugging behavior has also commonly been observed in *Andrena.* Davis & LaBerge (1975) observed *A. erigeniae* bringing soil up and plugging the nest about a centimeter from the surface and postulated that the bees were digging cells or a new burrow shaft. Linsley & MacSwain (1958) observed the same behavior in *A. complexa* and *A. suavis* and Thorp (1969) observed similar behavior for *A. chalybaea.* Although plugging of all burrows in the nest aggregation never occurred, plugging seemed to occur only at the end of a series of foraging trips in *A. regularis.* This seems to indicate that the plugging of the main burrow was associated with digging of a new cell or burrow shaft.

Nest Recognition and Defense

Both *A. carlini* and *A. regularis* females seemed able to locate their nests and enter quickly, especially several days after nesting had begun. Earlier in the nesting season, disorientation was observed with females spending a few minutes to several minutes in finding their nests. Such variations in locating nests have been reported for several *Andrena.* Some disorientation may have been caused by the observer when excavating nests, and by the disruption of activity by parasites and predators. Early season disorientation is more common and females seemed to need to perform an orientation flight more often. Usually only one orientation flight per day was needed, and that was early in the day when the female first left her nest.

Davis & LaBerge (1975) state that nest recognition is due to both visual and olfactory clues. Recent advances have been made in determining the nature of compounds that have odoriferous qualities in *Andrena.* Bergstrom & Tengo (1974) reported that the Dufour's gland was relatively large in the genus *Andrena* and reached maximum size during nest construction. Furthermore, they reported that the gland seems to have two functions—it acts as an adhesive for nest galleries and as an odoriferous agent. Secretions from six species of *Andrena* were chemically analyzed *(bicolor, denticulata, nigroaenea, carbonaria, helvola* and *haemorrhoa)* and the main volatile components were identified as fornesyl and geranyl esters.

Behavioral observations of bees also indicate that nest marking occurs. Bergstrom & Tengo (1974) mentioned that *Andrena ovina* pressed its abdomen towards the entrance of the nest prior to departure. An anthophorid bee, *Eucera longicornis,* similarly pressed its abdomen against entrance walls, especially when the nest had been invaded by ants. Abdomen pressing was not observed in *A. regularis* or *A. carlini,* but marking of nests remains as a plausible explanation for burrow locating.

The aggregating behavior of *A. regularis,* as well as other species of *Andrena,* can also be understood in terms of olfactory stimuli. Bergstrom & Tengo (1974) reported that males and females of *A. flavipes* remained in nest areas due to odor characteristics of the nest site. Davis & LaBerge (1975) suggested that early emergers may attract later emergers by odor characteristics of newly excavated nest burrows. The tendency for some bees, such as *A. regularis,* to aggregate probably is of selective advantage, assuming that the early emergers choose the most suitable nest sites in a field and that the nest odor characteristics are important in locating the aggregation by incoming foraging bees. However, parasite pressure must override such advantages at times and dispersal must take place either after a site reaches saturation or before.

Defense of the nest by *A. regularis* was observed to be rather passive. Michener & Rettenmeyer (1956) observed that *A. erythronii* was not aggressive toward other bees, and Davis & LaBerge (1975) noted that *A. erigeniae* retreated when the entrance of its nest was invaded by a nabid bug. Avoidance tactics seemed to be used by *Andrena* females, rather than active defense of their nests.

Foraging and Provisioning

Both *A. regularis* and *A. carlini* are polylectic bees, a common adaptation of early spring bees. Sampling of pollen from females and from pollen in cells of both species indicated that pollen from *Prunus pennsylvanicus, P. virginiana, Aronia arbutifolia, Crataegus* sp., *Amelanchier* sp., *Malus* sp., and *Fragaria* sp., were all used at least to initiate nesting. Later, as blueberry plants came into bloom, most or all of the pollen brought into the nest was blueberry pollen.

The molded provisions of *A. carlini* and *A. regularis* are indistinguishable. Stephen (1966*a*) described a pollen mass for *A. viburnella* that was similar to that of *carlini* and *regularis* in that it was not a spherical ball but was craterlike. The *viburnella* pollen mass seems to be more deeply craterlike than that of either *regularis* or *carlini.* It was noted that the consistency of the pollen in cells of the same burrow, especially during larval development, varied from a soupy mass to a dry, cakey mass. Whether this was a change in the pollen mass after the larvae began feeding or occurred before the egg was laid, was not determined. Cells with eggs all had cakey, dry pollen masses and some of the cells with larvae did not have a semiliquid mass but remained cakey.

Foraging activity for both *A. carlini* and *A. regularis* in Mohannes field was continuous from early in the morning until sunset. Females did not usually begin foraging until the temperature reached about 13°C, and days in which the temperature dropped suddenly found more females returning to the nests early than on other days. Inclement weather stopped foraging activities, although both species did bring pollen into their nests on mild, light rainy days. As mentioned above, foraging was also interrupted by digging activities of the females.

Foraging trips for *A. regularis* ranged from 23 to 272 minutes. No such information was recorded for *A. carlini,* but it seems likely that the time spent foraging is similar to that of *regularis.* Foraging time is highly variable for other species of *Andrena*. Michener & Rettenmeyer (1956) noted that trips for *A. erythronii* varied from 27 to 235 minutes. Stephen (1966*a*) reported a range of 18 to 52 minutes for *A. viburnella* and suggested that this difference in range was because *viburnella* was polylectic and *erythronii* oligolectic in foraging habits. This seems unlikely since both *carlini* and *regularis* are polylectic and have forage time range similar to that of the oligolectic *erythronii*. Davis & LaBerge (1975) point out that adverse weather conditions in early spring probably prolonged foraging times of *A. erigeniae*, an oligolectic bee. Low temperatures and rainfall are common in New Brunswick in May and probably have a similar effect on *carlini* and *regularis* foraging times.

Time spent in the nest for *A. regularis* ranged from 10 to 97 minutes. A few observations indicated that *carlini* remained in the burrow for periods of 15–55 minutes, but this data is inadequate. Michener & Rettenmeyer (1956) recorded a range of 17–88 minutes in the nest for *A. erythronii*. According to Stephen (1966*a*), *A. viburnella* spent 6.5–33 minutes in the nest between foraging times. Davis & LaBerge (1975) observed that *A. erigeniae* remained in the nest an average of 7.5 minutes, from a range of 4 to 31 minutes. Stephen (1966*a*) postulated that the differences in nest time might be due to whether or not the females fashioned a pollen ball. But *A. regularis* females usually remained in the nest until the next day after completing a pollen ball, plugging the completed cell and burrow and digging a new one. This does not seem to fit with Stephen's hypothesis. Irregular weather and low temperatures in May and early June in New Brunswick probably affect time spent in the nest by females of *carlini* and *regularis*, just as it affects the range of time of these females spent in foraging.

Observations of female bees foraging on blueberry blossoms were made in Mohannes field, but whether these were *A. carlini* or *A. regularis* could not be determined in the field. At about 1200 hours on 7 June 1976 females averaged 17.2 ± 0.99 second (N = 25) per blossom. At about the same time of 8 June 1976, females averaged 10.9 ± 1.06 seconds (N =28) per blossom. This time difference observed from one day to the next can be attributed to the less optimal weather on 7 June when the noon temperature was only 18.3°C and it was quite windy.

Immature Stages

Eggs of both *A. carlini* and *A. regularis* were placed more or less erect on the pollen mass, similar to the placement of the egg of *A. viburnella* (Stephen 1966*a*). Other species of *Andrena*, that have spherical pollen balls either place their eggs almost parallel to the surface with only one end touching as in *erigeniae* (Davis & LaBerge 1975) or flat against the pollen ball as in *suavis* and *complexa* (Linsley & MacSwain 1958), *accepta* (Rozen 1973) or *candida* (Youssef & Bohart 1968). The eggs of both *carlini* and *regularis* were elongate, slightly bowed, enlarged at one end and nearly 3 mm in length and 1 mm in width. These eggs are slightly larger than most eggs of *Andrena* thus far reported except the egg of *A. placida* (Thorp & Stage 1968). However, *placida* is a bee of comparable size to *regularis* and *carlini* and most of the other bees reported are slightly to considerably smaller.

Both *A. carlini* and *A. regularis* began nesting at about the same time in Mohannes field in 1977 (20–21 May). Burrows of both species dug later in the season indicate that *regularis* larval development was further advanced than *carlini* larval development. This difference may be entirely incidental to the age of the particular nests excavated by the observer.

No postdefecating larvae were found for either *A. carlini* or *A. regularis*, since this study was terminated on 22 June 1976 and 27 May 1977. Packard (1868) reported fully grown larvae of *regularis* (determined as *A. vicina*) were present by 29 June, pupae by 1 August and fully formed adults by 24 August. This is similar to other univoltine vernal *Andrena* (Davis & LaBerge 1975; Michener & Rettenmeyer 1956) and *carlini* probably follows the same order of events.

The predefecating larva of *A. regularis* is described above. No predefecating larvae of *A. carlini* were taken but earlier stages were essentially identical to those of *regularis*. The *regularis* larvae resembled those of *A. candida* (Youssef & Bohart 1968) in head and spiracles.

Inquilines and Parasites

The anthomyiid fly, *Leucophora fusca*, seemingly is an inquiline of both *A. carlini* and *A. regularis*. This fly was observed shadowing *regularis* females and entering *regularis* nests, and fly larvae were found in cells of both *carlini* and *regularis*. How the fly larvae get into the cells of these bees is unknown. Huie (1916) reported a Scottish *Leucophora* lays its eggs on the burrow floor of *Andrena* just inside of the entrance. Stephen, Bohart & Torchio (1969) suggest that *Leucophora* flies lay their eggs on the female's pollen mass as it is brought to the nest. Michener & Rettenmeyer (1956) noted that *Leucophora obtusa*, when pursuing *A. miserabilis (= bipunctata)*, inserted eggs into the loose soil of the tumulus. Davis & LaBerge (1975) noted that all cells of *A. erigeniae* with fly larvae were also filled with fungus and that it seemed that the larvae probably entered the cell after it was completed, thus destroying the antibiotic nature of the cell contents. Also, different ages of fly larvae within the same cell indicate that they had arrived in the cell at different times. In both *carlini* and *regularis* nests, cells were found with two, slightly different-sized anthomyiid larvae. Also, *Leucophora fusca* was observed to enter the *regularis* nest and no eggs were found or observed laid on tumulus, pollen mass of females or just inside the burrow entrance.

An undetermined bombyliid fly was observed repeatedly laying eggs on the soil in the *A. regularis* aggregation. No larvae of this fly were seen either in the nest or on the soil near the nests. On two occasions *Nomada imbricata* females were observed entering burrows of *regularis.* Again no larvae of this *Nomada* were found in either *regularis* or *carlini* nests, although it is likely that it is an inquiline of of both species of *Andrena.*

Although Pinto & Selander (1970) reported that *Meloe angusticollis* is probably a larval parasitoid of *A. carlini* in Illinois, no coleopterous larvae were found in either *carlini* or *regularis* nests in New Brunswick. Pinto & Selander (1970) base their opinion on finding a total of 164 first instar triungulin larvae of *M. angusticollis* on 19 females of *carlini* collected on *Dentaria laciniata, Claytonia virginica* and *Taraxacum officinale* in Illinois.

The incidence of stylopization is negligible for both *A. regularis* and *A. carlini.* A total of 250 specimens of each species of bee from Mohannes blueberry field were examined and none was found to be stylopized. Bouseman (personal communication) stated that *regularis* and *carlini* are probably never stylopzed and that a study of the subgenus *Melandrena* indicates that the group of species to which *regularis* and *carlini* belong are rarely, if ever, stylopized, whereas the other large group of *Melandrena* species are frequently stylopized. Since these groupings of *Melandrena* are presumed to be phylogenetic, the degree of stylopization seems to be related to the phylogeny of the group. Robertson (1910) did not find *A. carlini* to be stylopized in Illinois and stated that most *Andrena* species bearing *Stylops* are small species.

LITERATURE CITED

Atwood, C. E. 1933. Studies on the Apoidea of western Nova Scotia with special reference to visitors to apple bloom. Canadian Journal of Research 9:443–457.

Bergstrom, G., and J. Tengo. 1974. Studies on natural odoriferous compounds. IX. Farnesyl and geranyl esters as main constituents of the secretion from dufour's gland in 6 species of *Andrena* (Hym., Apoidea). Chemica Scripta 5:28–38.

Boulanger, L. W., G. W. Wood, E. A. Osgood, C. O Dirks. 1967. Native bees associated with the low-bush blueberry in Maine and Eastern Canada. Maine Agricultural Experiment Station Bulletin 26.

Davis, L. R., and W. E. LaBerge. 1975. The nest biology of the bee *Andrena (Ptilandrena) erigeniae* Robertson (Hymenoptera: Andrenidae). Illinois Natural History Survey Biological Note 95. 16 p.

Hirashima, Y. 1962. Systematic and biological studies of the family Adrenidae of Japan (Hymenoptera, Apoidea). Part I. Biology. Faculty of Agriculture, Kyushu University Journal 12:1–20.

Huie, L. H. 1916. The habits and life-history of *Hylemyia grisea* Fall., an anthomyiid fly new to the Scottish fauna. Scottish Naturalist 49:13–20.

Kevan, P. G. 1977. Blueberry crops in Nova Scotia and New Brunswick—pesticides and crop reductions. Canada Journal of Agricultural Economics 25(1):61–64.

Linsley, E. G. 1937. The occurrence of double broods in North American andrenid bees (Hymenoptera). Brooklyn Entomological Society Bulletin 32:125–127.

———, and J. W. MacSwain. 1955. Synonymy of *Nomada fowleri* Cockerell with *N. obscurella* Fowler (Hymenoptera: Nomadidae). Canadian Entomologist 87:440.

——— and ———. 1956. Further notes on the taxonomy and biology of the Adrenine bees associated with *Oenothera.* (Hymenoptera:Andrenidae). Pan-Pacific Entomologist 32:111–121.

——— and ———. 1958. Ethology of some *Ranunculus* insects with emphasis on competition for pollen. University of California Publications in Entomology 16:1–45.

———, ———, and Ray F. Smith. 1955. Observations on the nesting habits and flower relationships of some species of *Melandrena* (Hymenoptera:Andrenidae). Pan-Pacific Entomologist 31:173–185.

MacSwain, J. W. 1945. Nesting habits of *Andrena rhodotricha* Linsley (Hymenoptera:Andrenidae). Pan-Pacific Entomologist 21:134.

Michener, C. D., E. A. Cross, H. V. Day, C. W. Rettenmeyer, and A. Wille. 1955. Additional techniques for studying the behavior of wild bees. Insectes Sociaux. 2:237–246.

———, and C. W. Rettenmeyer. 1956. The ethology of *Andrena erythronii* with comparative data on other species (Hymenoptera, Andrenidae). University of Kansas Service Bulletin 37:645–684.

Osgood, E. A., Jr. 1972. Soil characteristics of nesting sites of solitary bees associated with the low-bush blueberry in Maine. Maine Life Sciences and Agricultural Experiment Station Technical Bulletin 59:1–8.

Packard, A. S., Jr. 1868. The home of the bees. American Naturalist 1:596–606.

———. 1897. Notes on the transformations of the higher hymenoptera. II. New York Entomological Society Journal 5: 77–87.

Perkins, R. C. L. 1919. The British species of *Andrena* and *Nomada.* Royal Entomology Society of London Transactions 67:218–319.

Phipps, C. R. 1930. Pollination studies on blueberry and huckleberry insects. Maine Agricultural Experiment Station Bulletin 356:114–116.

Pinto, J. D., and R. B. Selander. 1970. The bionomics of blister beetles of the genus *Meloe* and a classification of the New World species. Illinois Biological Monographs, No. 42:1–222.

Robertson, C. 1910. Hosts of Strepsiptera. Canadian Entomologist 42:323–330.

Rozen, J. G., Jr. 1968. Biology and immature stages of the aberrant bee genus *Meliturgula* (Hymenoptera, Andrenidae). American Museum Novitates 2331:1–18.

———. 1973. Biology notes on the bee *Andrena accepta* Viereck (Hymenoptera, Andrenidae). New York Entomological Society Journal 81:54–61.

Stephen, W. P. 1966*a*. *Andrena (Cryptandrena) viburnella.* I. Bionomics. Kansas Entomological Society Journal 39:42–51.

———. 1966*b*. *Andrena (Cryptandrena) viburnella*. II. External morphology of the larva and pupa. Kansas Entomological Society Journal 39:51–53.

———, G. E. Bohart, and P. F. Torchio. 1969. The biology and external morphology of bees, with a synopsis of the genera of northwestern America. Oregon Agricultural Experiment Station Bulletin. 140 p.

Thorp, R. W. 1969. Systematics and ecology of the bees of the subgenus *Diandrena* (Hymenoptera:Andrenidae). University of California Publications in Entomology 52:1–146.

———, and G. I. Stage. 1968. Ecology of *Andrena placida* with descriptions of the larva and pupa. Entomological Society of America Annals 61:1580–1586.

Youssef, N. N., and G. E. Bohart. 1968. The nesting habits and immature stages of *Andrena (Thysandrena) candida* Smith (Hymenoptera, Apoidea). Kansas Entomological Society Journal 41:442–455.

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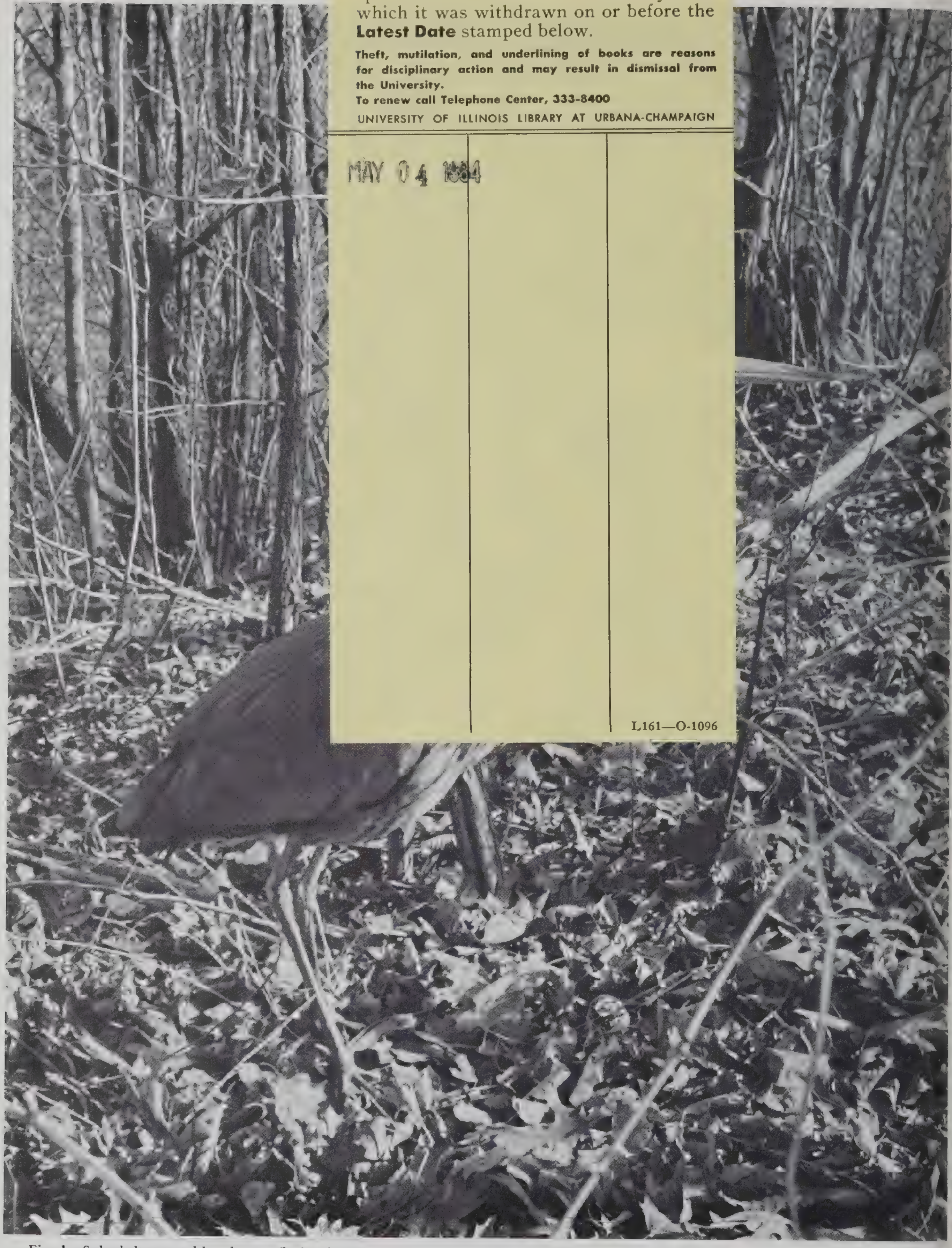

Fig. 1.—Subadult great blue heron (lacks the white crown and black head plumes of the adult). This largest Illinois heron stands a meter or more tall and is actually more gray than blue. Photograph by George W. Bennett.

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From 1973 through 1977 we attempted to locate nd census heron nesting colonies throughout the tate and adjacent boundaries by (1) inquiries to ther observers and (2) ground and air searches of uitable habitat. The potential habitat in Illinois as vast, and our search was not exhaustive. We did y most of the (Illinois) lengths of the Mississippi, llinois, Sugar, Kishwaukee, Rock, Fox (north), Kan-akee, Vermilion (north), Embarras, Kaskaskia, Wa-ash, Little Wabash, Elm, Fox (south), Big Muddy, ittle Muddy, Cache, and Ohio rivers, plus Crooked reek (west of Centralia) and the Skillet Fork. The lights were made mainly in May and July, 1973–1977 y R. R. Graber. A number of suitable looking, po-ential nesting areas were not covered for lack of time nd funds. Notable among these were major branches f the Kaskaskia (Silver and Shoal creeks), the Big Muddy (Galum and Beaucoup creeks), and the Illi-ois (Macoupin Creek, La Moine, Spoon, and Mack-naw rivers), plus the Green River and numerous maller streams. There may be many colonies that ve have not found. Lusk Creek, a relatively small tream in Pope County, has had at least three heron-ies in the past 15 years, and there are many streams f similar nature that we have not searched. Except or the Mississippi, Illinois, Kaskaskia, Ohio, and Wa-ash rivers, our aerial surveillance included only one rip per stream, and we may have overlooked colo-ies. In at least two instances we learned that we had lown past colonies without detecting them. Heron olonies may also have been established on some treams after we searched them. We began our search n 1973, and our census record is least complete for hat year, improving in subsequent years. Our aerial urveillance trips were almost always made in a high-winged Cessna 150 or 172, flown 122–244 meters above local terrain at an air speed of 115–130 km per hour. When we found a colony, we circled in flight turns 244 meters directly above it, and looking through 7 × 50 binoculars, attempted to count active nests. We also attempted to determine nest contents, but it was often very difficult even to see the nests. This was particularly true of colonies in stands of silver maples and cottonwoods, notably on the Illinois River. Nests were easier to count in sycamores, cypress, gum, and dead trees. Though we attempted to count individual nests, in tabulating the counts (e.g., Table 1) we have rounded figures above 5 to the nearest 5 nests in recognition of the difficulty of obtaining truly accurate counts.

We also attempted to census most of the colonies from the ground. For larger herons aerial counts were often higher than ground counts, the disparity probably resulting from one or more of these causes: (1) some colonies (e.g., Shobonier before 1975) had nests widely dispersed over large areas (2 km^2), making it difficult to find all nests from the ground, (2) inactive nests or clusters of branches, which looked like nests, were counted as active nests from the air, and (3) nests were sometimes counted more than once from the air. Another source of discrepancy between air and ground counts stems from wind damage to colonies. When we visited the East Dubuque, Sabula, and New Boston colonies, 22–24 July 1974, we found that many nests had been destroyed by a windstorm in June, and the damage had not been detected by R. Graber's census flight in early July. The number of active nests (pairs of breeding herons) had actually been much larger before the storm. Another possible source of error stems from the habit of herons—at least great blues and great egrets—of occupying colony sites (even deserted sites) temporarily during their spring migration. Single counts of colonies, especially if made before May, may include birds at nests that will not be used for nesting.

We were concerned about the effects of our visits upon the colonies and tried, both during air and ground surveillance, to keep our visits as brief and unobtrusive as possible; we visited each colony no more than twice (once from the air and once from the ground) per year. During our ground visits to colonies, we: (1) counted active nests of each species, (2) tried to ascertain the number of large young per nest, (3) collected food items disgorged by nestlings, (4) identified and counted nest trees, and (5) measured nest heights and sizes of nest trees. Nest heights were measured with an optical device (Optical Tapemeasure) with an accuracy range of 6.3 cm

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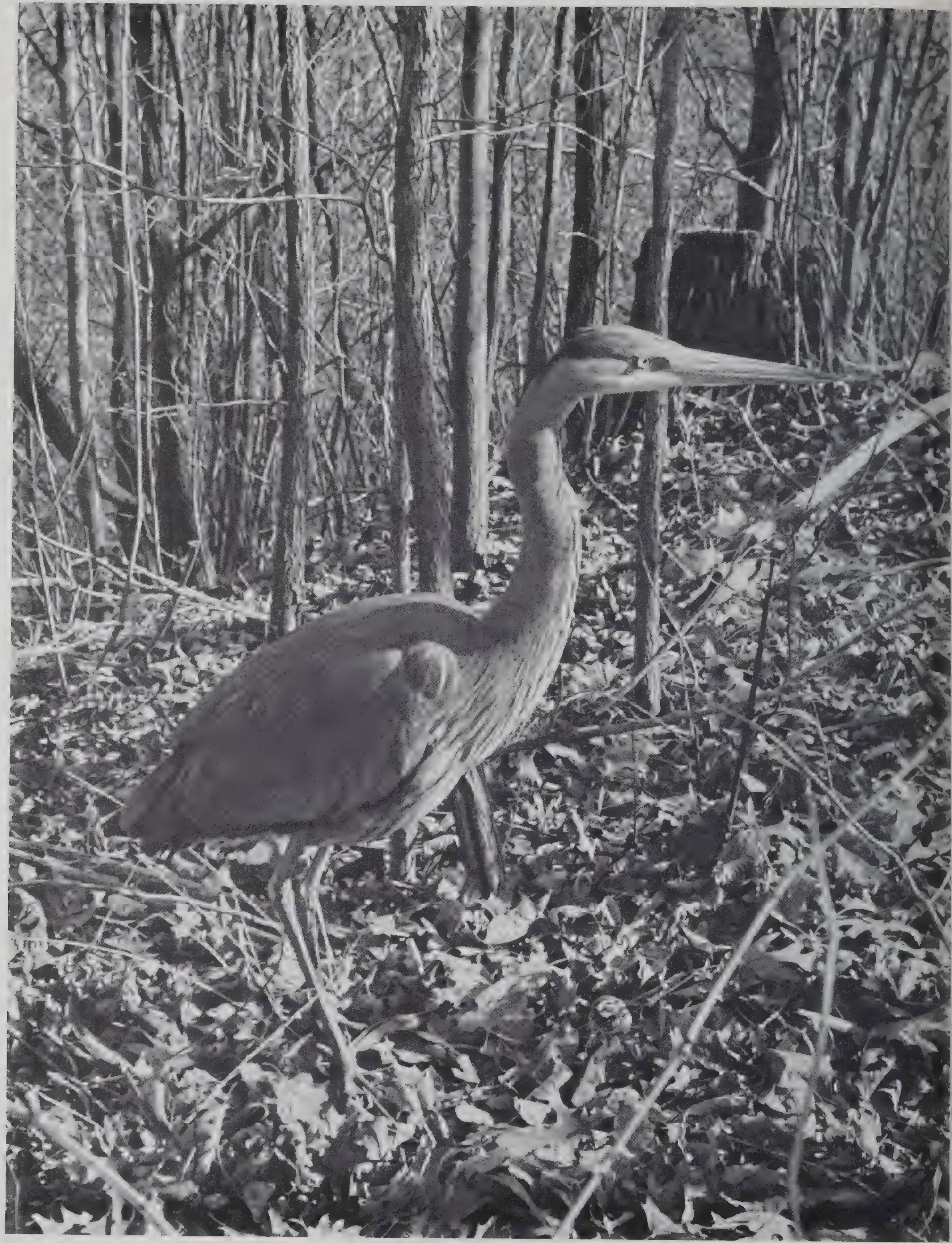

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at a distance of 7.6 m and 0.8 m at 30.5 m. We rounded all readings to the nearest 1.5 m.

Because of the demonstrated relationship between chlorinated hydrocarbon pesticide pollution and eggshell thinning in herons (Faber et al. 1972), we measured some eggshells of great blues and great egrets. Most of our visits to colonies coincided with the latter part of the nesting cycle, by which time eggshells on the ground were usually badly broken, but in 1977 we retrieved some eggs intact enough to measure. The sample was fortuitous and may be biased in a number of ways, but there was no possibility of confusion of species. We also measured several areas of each shell. We measured shell thickness with a Starrett Micrometer Caliper that was equipped with a constant-pressure screw and graduated in 10-micron units. With a magnifier, we attempted to estimate to the nearest micron. The accuracy of the instrument, checked against a standard as well as another instrument, was precise, and our reading accuracy fell easily within 5 microns. In this paper we have, for the first time in this series, converted all measurements to metric units.

Food samples, which we collected at the heronries, were often partially digested, and we preserved them as soon as possible in formaldehyde to halt decomposition. To determine size classes of the food specimens, we compared the undigested parts—most often the tails—with intact specimens. To estimate biomass, we used data compiled by Carlander (1950 and 1969) to convert fish length to weight.

In referring to colony locations, we have used the names found in published references to the sites, or the names of places (towns, lakes, etc.) closest to the colonies that can be found on the U.S. Geological Survey quadrangle maps. Our occasional references to hearing the migration of one species or another relate to a study made in central Illinois—mainly Champaign County—in which night sounds were recorded between the hours of 7:00 p.m. and 6:00 a.m. CST from 21 March to 1 June and from 17 August to 18 November 1957–1960 (Graber & Cochran 1959).

We are most particularly indebted to Frank C. Bellrose, who generously provided us with location and census data on many of the heron colonies of the Illinois and Mississippi rivers. John Schwegman and Alvin C. Lopinot permitted us to use unpublished data from their respective papers on heronries in southern Illinois, and Richard G. Bjorklund allowed us to use unpublished data from his studies on two Illinois River colonies. Dr. Bjorklund also reviewed the original manuscript of this paper.

A number of contributions of data from many sections of the state were made by staff of the Illinois Department of Conservation, including Conrad Foley, Walter Reeve, Jim Lockart, Floyd Kringer, Jared Garver, Donald Siweck, Robert Cottingham, Jerry Schaefer, Charles Wahrenburg, David Klinedinst Robert Williamson, John Stambaugh, and Herman Hier.

Peter Dring, Lawrence Balch, Harlan Walley Jack Oar, Charles D. Hudson, Maryann Gossmann Jerrold Olson, Mrs. Ed Laechelt, Robert Montgomery, Janet Tebussek, Charlie Swanson, and William Hartman provided valuable historical and other data on heron populations in northern Illinois. Marilyn Campbell, Dale Birkenholz, C. Turner Nearing, Richard Sandburg, Richard Palmer, Frank Irwin, James Funk, Mahlon Mahoney, Lynn McKeown, Darlene Friedmann, Louise Augustine, June and Russell Meece, Russell Mumford, and William H. Elder provided data on populations in central Illinois or adjacent areas. Paul Heye, Merril McHenry, Richard Rodrian, Lucas Wrischnik, Philip Short, James O. Smith, Lawrence Maedeker, Paul Roush, Denny Jones, Max D. Hutchison, and Michael Morrison provided data on southern Illinois or adjacent areas.

William L. Anderson (now with the Illinois Department of Conservation) and James W. Seets censused the Plainfield heronry and collected fish specimens for us there in 1973. They also explored for heronries by boat on the Mississippi River between St. Louis and Cairo and on the Wabash and Ohio rivers between Mt. Carmel and Paducah, Kentucky in 1976.

The late George W. Bennett permitted us to use his fine photograph of a great blue heron, and William J. Beecher, his dramatic photograph of herons against the moon. We are also indebted to Robert Starr for permission to use his photographs of nesting snowy egrets and little blue herons and to Beverly Sanderson for the use of her drawing of a yellow-crowned night heron.

Several of our colleagues at the Illinois Natural History Survey provided valiant service in the identification of often badly mangled food specimens from herons. We are especially grateful to Larry Page, Brooks Burr, and Philip W. Smith for their work on the fishes and crayfish; Michael Morris, who identified toads and frogs; Don Webb, Wallace LaBerge, John Bouseman, and George Godfrey, who identified insects; and John Unzicker, who identified spiders and slugs.

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GREAT BLUE HERON *(Ardea herodias)*

(Fig. 1 and 2)

Spring Migration

Though great blue herons may be found in Illinois in winter, most of them migrate well to the south of Illinois and do not usually begin to reappear in the state until late February and March. February records may refer either to birds that have wintered in Illinois or to early spring arrivals (Brown 1964, Cooke 1913, Nolan 1958*a*). Lopinot (1950) recorded the first arrival of herons at a southern Illinois colony site on 23 February, and in northern Illinois great blues arrived at a colony on 19 March (Smith 1942*a*). Most of the Illinois breeding population probably returns in March (after 12 March) and April, with some more northern populations passing through the state even in May (Fig 3).

Because herons range so widely, there is the possibility of confusing local foraging flights with migration, and the characteristics of the migration are virtually unknown. Grasett (1926) saw seven birds take off from deep water near Glencoe on 4 April; he believed that they were migrating and had settled on the water to rest (see also Keller 1966). In Vermilion County on 27 April 1977, William R. Edwards observed four great blues in a line formation fly over about dusk, moving directly north, but crabbing into a strong west wind. This may have been the beginning of a night migration. William J. Beecher photographed herons (possibly great blues) migrating at night as they crossed the light of the moon about 11 p.m. on 16 April 1976 at Chicago (Fig 4).

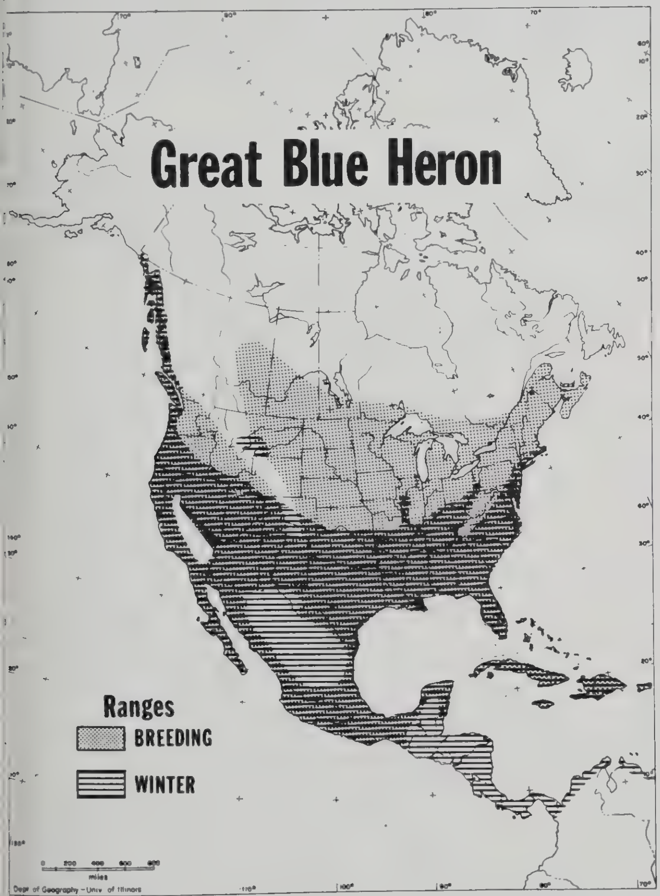

Fig. 2.—General distribution of the great blue heron.

Distribution

The great blue heron breeds throughout much of North America (Fig. 2). In Illinois nesting great blues are now found primarily on the major rivers (Fig. 5 and Table 1). A colony near Davenport was not plotted for lack of precise data on its location (Hodges 1954). There are records of colonies or isolated pairs on smaller streams (e.g., Timber Creek in McLean County, Calef 1953; Lusk Creek in Pope County, etc.), but there appear to be few such colonies left (Table 1). The absence of records for some major drainages, including the Little Wabash and Embarras rivers, both of which still have large areas of excellent-appearing habitat, is surprising. Also largely devoid of great blue heron breeding records are the Pecatonica, Rock, Green, upper Illinois (above Ottawa), Kankakee (in Illinois), both Vermilions, La Moine, and Sangamon rivers, most of which may have been ruined as heron habitat before they could be explored by ornithologists. The Kankakee drainage in Indiana supported extensive colonies in the last century (Butler 1897, Deane 1897), and the habitat east of Momence still looks suitable for herons. So far as we can determine, all of the northeastern Illinois colonies are gone. We would expect other great blue heron colonies to be discovered in the state, but at the rate that they are presently disappearing, if not found soon, they are likely to go undiscovered.

Great blues away from colonies may be found in all parts of the state in almost any month. Great blues were uncommon but usual items in Indian midden deposits throughout the state, constituting about 0.2 percent of identified bird remains and dating back to perhaps 2000 B.C. (Hill 1966, Parmalee 1957, 1962*b*, 1964, and 1969 and Parmalee et al. 1972).

Nesting Habitats and Populations

Almost invariably great blue herons nest in bottomland forest habitat, usually within extensive tracts and not usually at the edge. The sizes of the nesting tracts for the 28 largest extant (or recently extant) great blue heron colonies in Illinois ranged from about 103 to 1,969 ha, with an average of 608 ha, a remarkably large area considering the de-

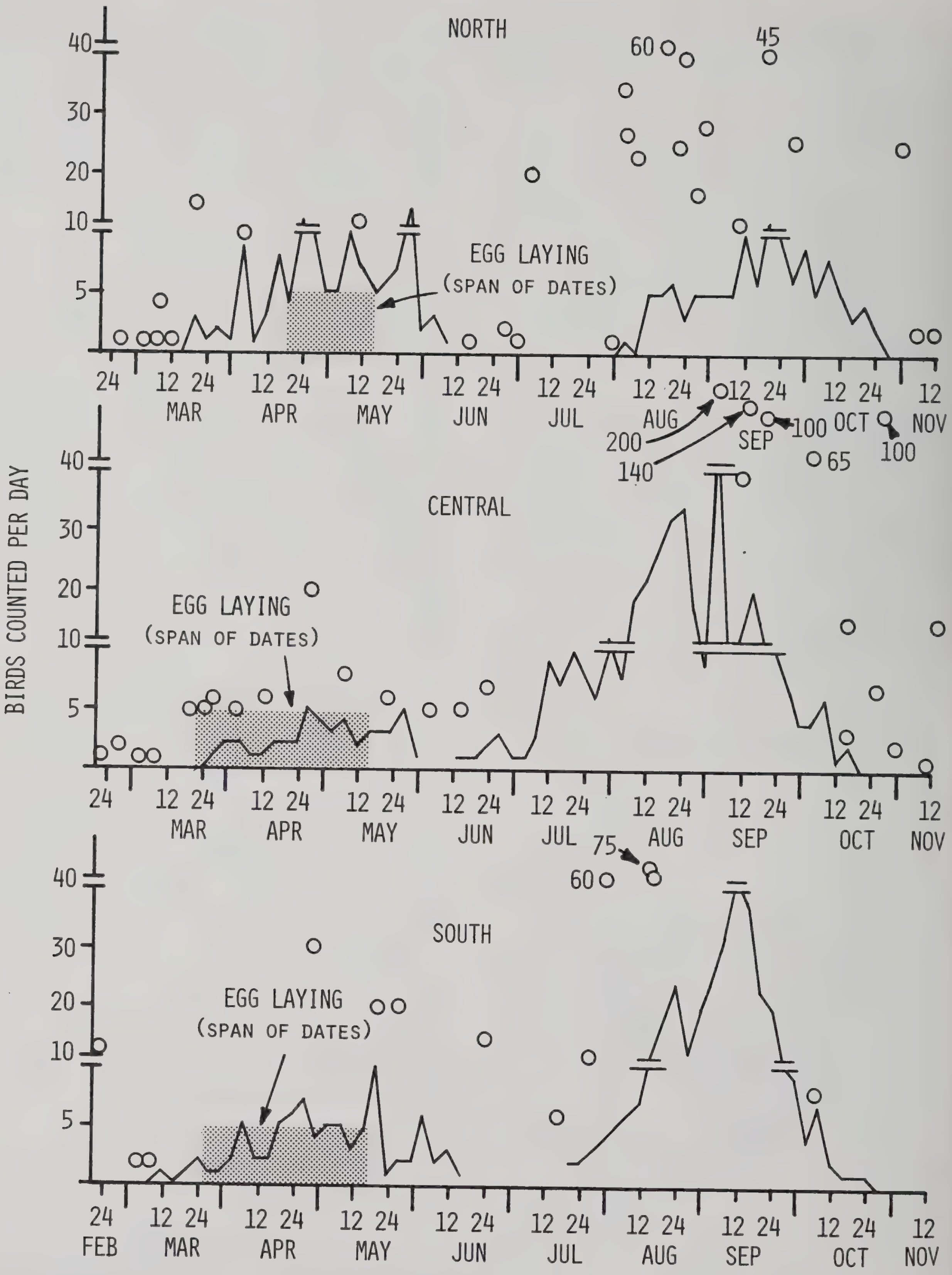

Fig. 3.—Egg-laying and migration seasons of the great blue heron in different regions of Illinois (see Fig. 7 for regions). Spring and fall graph lines show the highest daily count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

Fig. 4.—Migrating herons seen against the moon over Chicago at about 11:00 p.m., 16 April 1976, as photographed with a telephoto lens by William J. Beecher, Chicago Academy of Sciences.

gree to which lowland forest has been decimated in recent decades. The Clear Lake and Rend Lake colonies were excluded from this calculation for lack of data on tract size. Apparent exceptions to this use of large tracts for nesting were the colonies of northeastern Illinois, some still present at least into the 1960's, at sites (Lake Forest, Barrington, McHenry, Belvidere, Cherry Valley) without extensive forests. However, most of these colonies were small and apparently have not survived, with the exception of the Chemung colony. The concealment value of an extensive tract may be important to colony survival. Most of the colonies are also over water during part or all of the nesting cycle, thus reducing accessibility to potential predators.

The nesting habitat is reflected in the kinds of nest trees used, generally typical floodplain species (Table 2). Lopinot (1950) recorded swamp cottonwood as the dominant nest tree at Crab Orchard Lake. Our counts indicate that the tree species most used by great blues are silver maple, sycamore, cottonwood, bald cypress, and tupelo, but there is regional variation in the species used. Elm (now virtually all dead) is a primary nest tree in northwestern Illinois, but nowhere else. Barnes (1909) implied that great blues showed a preference for sycamores and cottonwoods to elms of equal size. Sycamores are not generally numerical dominants in lowland forests, but the species is second only to silver maple in its use by great blues. Silver maples and cottonwoods, on the other hand, are often dominants in bottomland forests. Oaks, hickories, willows, and ashes are also often dominants, but are relatively little used by great blues (Table 2). Hammerslough & Bjorklund (1968) and Bjorklund (1975) observed that cottonwood was the dominant nest tree for great blues at Pekin, whereas egrets made more use of silver maples, and night herons more use of green ashes.

Among the tree characteristics that great blues choose for nesting, size must be important. Though sycamores are not numerical dominants, they are often the largest trees in a stand. Most great blue nests are placed high in the largest available trees. Heights of great blue heron nests ranged from 14 to 29 m and averaged 21 m for all nest trees measured (Table 2). At Pekin great blue nests ranged in height from 18 to 24 m (Hammerslough & Bjorklund 1968).

The nest-site areas are only part of the essential breeding habitat. Aquatic foraging areas, which may lie outside as well as within forest areas, are essential. This foraging habitat has never been precisely defined either in physical terms or in terms of the

Great Blue Heron

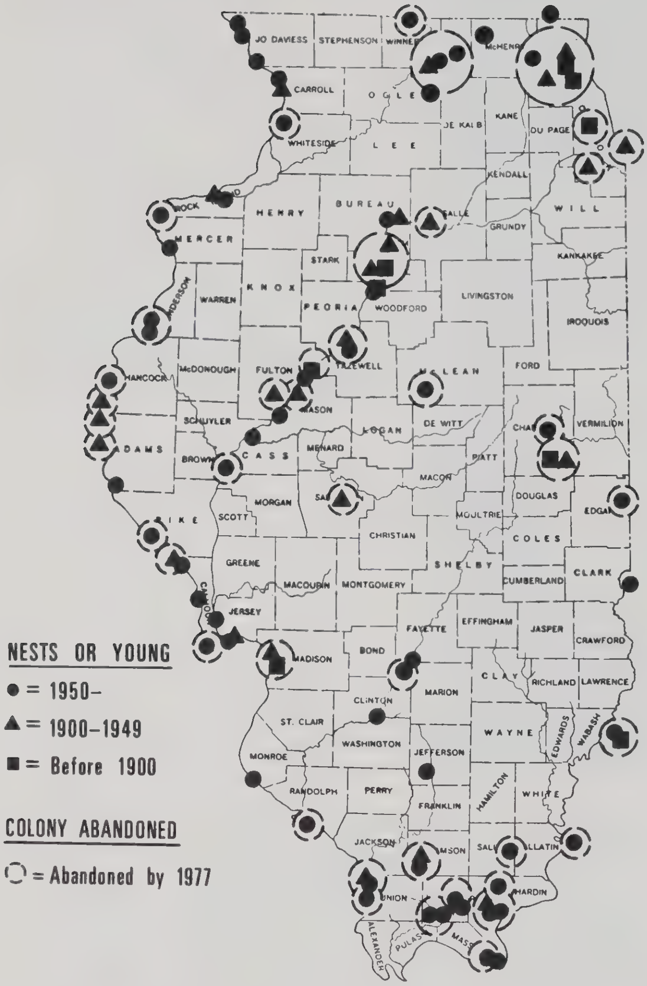

Fig. 5.—Distribution of nesting colonies of great blue herons in Illinois. Note that encircled colony sites were apparently abandoned as of 1976–1977.

fish populations it supports (see food). There is rough correlation between the nesting heron population and the amount of surface water available within a particular drainage. The correlation coefficient (r) between numbers of heron nests and area of water surface for the 18 Illinois counties on the Mississippi River was 0.592 ($P = < 0.01$). The foraging habitat is not that simply defined, however, as Johnson County, which has relatively little surface water, has a relatively high nesting population of great blues. Great blue populations might be better correlated with area of backwater, but acreage data are not available for that particular habitat. Backwaters are characteristic of the major Illinois rivers and of southern Illinois, which also constitute the primary nesting range of the great blue in Illinois. It is our impression that the great blue is particularly associated with the natural floodplain sequence in which lagoons are filled by spring floods on major streams, dry back as summer progresses, and concentrate fish populations as the food requirements of nestling herons reach their peak.

Because great blue heron colonies are generally located in isolated areas, we expected the great blue population to be inversely correlated with the human population of a county. The relationship appeared to be negative ($r = -0.229$) but was not significant. With one exception, however, the largest great blue colonies were in counties with less than 25,000 human inhabitants. Rock Island County and adjacent Iowa have over 265,000 people, and the large heron colony near Andalusia is presently declining. We know of no extant great blue colonies in the most populous counties (Cook, Lake, Du Page, Winnebago, Madison, St. Clair). One of the largest recently established colonies in the state was near Peoria, but it had declined to zero by 1974 (Bjorklund 1975).

Including bibliographic records dating back into the last century, some data exist on about 90 great blue heron colony sites in Illinois and adjacent areas (Table 1). Many of the published records are vague or very incomplete, and the number of colonies cannot be determined precisely. Barnes (1909) referred to a colony near Lacon which he believed had been in existence since the first settlement by whites. He personally had known of its existence since at least 1888, but the site was abandoned by 1909. Colony site(s) near Depue have been occupied since at least 1934 (Bartel 1934*a* and *b*). The relationship of the colony population to the colony site is unknown, and only extensive banding can show whether a given site is occupied every year by the same birds or their descendants, or what happens to the population when a site is deserted.

Of the 90 colonies on record, we know of only 34 that have been occupied since 1973, and 10 of these were deserted between 1973 and 1977. The loss of a colony site does not necessarily mean the loss of the population, however, and what happens to the birds when a colony site is abandoned is generally unknown. This lack of information, plus annual variation in the population and the difficulty of censusing colonies, makes any evaluation of long-term population change very difficult.

If, as an index, we refer to colonies for which there are both past and recent data on numbers of nests, there are indications of serious decline in the great blue heron population of Illinois. For the 25 colonies in this category, representing all regions of the state, the annual number of nests was 1,571 (using only the most conservative counts) before 1970, and 455 after 1970, a decline of 71 percent. There was about a 55-percent decline in nests at seven colonies between the 1960's and 1970's, including the loss of the Pekin colony studied by Bjorklund

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
		Mississippi River Area							
East Dubuque	Jo Daviess				...	70[a]	90	40	20
Menominee	Jo Daviess				...	5	5	20	...
Savanna Depot	Jo Daviess	1972	95	W. J. Hartman (unpublished)	...	50	110	90	...
Sabula, Iowa	Jackson	1942	P[b]	DuMont & Smith (1945)					
Sabula, Iowa	Jackson	1943	160[c]	Harlan (1943, 1945)					
Sabula, Iowa	Jackson	1944	"Hundreds"	Harlan (1945)					
Sabula, Iowa	Jackson	1945	"Hundreds"	Harlan (1945)	...	70	120	115	...
Clinton	Whiteside	1966	50	W. H. Brown (1966), Petersen & Ward (1966)	...	0	0	0	...
Davenport, Iowa	Scott	1890	4	Hodges (1954)					
Andalusia	Rock Island	1949	25[c]	Hodges (1950)					
Andalusia	Rock Island	1950	Declined	Hodges (1951)					
Andalusia	Rock Island	1965	P	Brown (1965)					
Andalusia	Rock Island	1966	100[c]	Petersen & Ward (1966), W. H. Brown (1966)					
Andalusia	Rock Island	1969	P	Brown (1969)	65	25	25	20	10
Muscatine (south)	Mercer	?		Bellrose (unpublished)	...	0	0	0	...
New Boston	Mercer	1955	250[c]	Greer (1955)					
New Boston	Mercer	1956	400	Nolan (1957)					
New Boston	Mercer	1957	570	Nolan (1957)					
New Boston	Mercer	1958	P	Nolan (1958*b*)					
New Boston	Mercer	1959	P	Mumford (1959)					
New Boston	Mercer	1962	135[c]	Brown (1962)					
New Boston	Mercer	1963	50	Brown (1963*b*)					
New Boston	Mercer	1965	P	Greer (1966)	10	45	35	25	45
Burlington, Iowa, Skunk River	Des Moines				20	40	5	0	...
Lomax	Henderson				...	5	0	0	...
Keokuk, Iowa, Des Moines River	Lee		P	Bellrose (unpublished)	0	0	0	0	...
Taylor Island	Hancock	1937?	80	Angus (1937)	0	0	0	0	...
Long Island	Adams	1937?	20	Angus (1937)	0	0	0	0	...
Shandrew Island	Adams	1925	14	Musselman (1926)	0	0	0	0	...
Lima Lake	Adams	1932?	50	Musselman (1932*b*)	0	0	0	0	...
McDonald Island	Adams				35	45	30	25	...
Boyd Island	Pike				...	25	10	0	...
Atlas	Pike	1948	50	Musselman (unpublished)	0	0	0	0	...
Clarksville (north), Mo.	Pike	1941	P	Jenkins (1942)					
Clarksville (north), Mo.	Pike	1942	P	Jenkins (1942)	0	0	0	0	...
Clarksville (south)	Calhoun	1942	40	Cunningham & Spotswood (1942)					
Clarksville (south)	Calhoun	1945	100	Cunningham (1945)					
Clarksville (south)	Calhoun	1951	P	Anonymous (1951)	120	80	45	30	50
Hamburg	Calhoun				100	40	60	35	50
Old Monroe, Mo.	St. Charles				...	...	60	0	...
Grafton No. 1	Jersey	1939	22	Jones (1939*a*)	0	0	0	0	...
Grafton No. 2, Mo.	St. Charles				...	0	0	3	...

(Table 1 continued on next page.)

Table 1.—Continued

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
Alton	?	1941	6	Cunningham (1941)	0	0	0	0	...
Fults	Monroe		P	Fleig (1971)	35	60	20	15	10
Kaskaskia	Randolph				0	0	0	10	0
Wolf Lake, Big Muddy River	Union	Late 1940's	P	J. Schwegman (unpublished)					
Wolf Lake, Big Muddy River	Union	1950	213	Lopinot (1950)					
Wolf Lake, Big Muddy River	Union	1969	0	J. Schwegman (unpublished)	0	0	0	0	...
Ware	Union	About 1970	Colony started		30	60	45	30	0
		Illinois and Spoon River Areas							
Starved Rock	La Salle	1944	P	Bellrose (unpublished), Ries & Werner (1946)	...	...	...	0	0
Depue	Bureau	1934	P	Bartel (1934*a* and *b*)					
Depue	Bureau	1936	400	Bellrose (1938)					
Depue	Bureau	1947	300	Bellrose (unpublished), DuMont (1947*b*)					
Depue	Bureau	1958	250	Bellrose (unpublished)					
Depue	Bureau	1962	250	Bellrose (unpublished)					
Depue	Bureau	1964	75	Bellrose (unpublished)					
Depue	Bureau	1967	150	Bellrose (unpublished)	20	30	45	40	40
Hennepin	Putnam	1939	P	Bellrose (1939*b*)	0	0	0	0	...
Lake Senachwine	Putnam	1936	50	Angus (1937)	0	0	0	0	...
Henry	Putnam	1939	68	Bellrose (unpublished)	0	0	0	0	...
Sparland	Marshall	1958	60	Bellrose (unpublished)					
Sparland	Marshall	1962	0	Bellrose (unpublished)					
Sparland	Marshall	1964	0	Bellrose (unpublished)	0	0	0	0	...
Lacon	Marshall	Since first settlement	P	Barnes (1909)					
Lacon	Marshall	1888	42	Barnes (1909)					
Lacon	Marshall	1900	47	Barnes (1909)					
Lacon	Marshall	1904	67	Barnes (1909)					
Lacon	Marshall	1909	0	Barnes (1909)	0	0	0	0	...
Lacon No. 2	Marshall	1912	24	Barnes (1912)	0	0	0	0	...
Lacon No. 3	Marshall	1927	120	Barnes (1927)	0	0	0	0	...
Lacon No. 3(?)	Marshall	1936	50	Bellrose (unpublished)					
Lacon	Marshall	1939	4	Bellrose (unpublished)	0	0	0	0	...
South Marshall County	Marshall	1890	P	Barnes (1890*b*)					
South Marshall County	Marshall	1936	P	Barnes (1936)	0	0	0	0	...
Chillicothe (East Douglas)	Woodford-Marshall	1891	P	W. E. Loucks (unpublished)	...	0	0	0	...
Chillicothe (north)	Peoria	1968	107	Bellrose (unpublished)					
Chillicothe (north)	Peoria	1971	56	Bellrose (unpublished)	...	40	20	25	20
Pekin	Tazewell	1935	P	Bjorklund (1975)					
Pekin	Tazewell	1958	125	Bellrose (unpublished)					
Pekin	Tazewell	1962	279	Bjorklund (1975)					
Pekin	Tazewell	1972	41	Bjorklund (1975)	7	0	0	0	0
Spring Lake	Tazewell	1891	P	W. E. Loucks (unpublished)	...	0	0	0	0

(Table 1 continued on next page.)

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
Big Lake (Duck Island)	Fulton	1933?	P	Angus (1937)					
Big Lake (Duck Island)	Fulton	1938	70	Bellrose (1939*b*)					
Big Lake (Duck Island)	Fulton	1939	114	Bellrose (unpublished)	...	0	0	0	0
Clear Lake	Mason-Tazewell	1958	0	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1962	110	Bjorklund (unpublished)					
Clear Lake	Mason-Tazewell	1964	100	Bjorklund (unpublished)					
Clear Lake	Mason-Tazewell	1967	140	Bjorklund (unpublished)					
Clear Lake	Mason-Tazewell	1968	278	Bjorklund (unpublished)					
Clear Lake	Mason-Tazewell	1969	293	Bjorklund (unpublished)					
Clear Lake	Mason-Tazewell	1971	141	Bjorklund (unpublished)	118	...	62	...	95
Lake Chautauqua	Mason	1942	7	Smith (1942*b*)					
Lake Chautauqua	Mason	1944	12	Smith & DuMont (1944)	...	0	0	0	...
Lewistown, Spoon River	Fulton	19??	P	Strode (1917)					
Lewistown, Spoon River	Fulton	2 years later	0	Strode (1917)					
Grand Island	Mason				P	...	55	50	65
Stewart Lake (upper point)	Mason	1939	80	Bellrose (unpublished)					
Stewart Lake (upper point)	Mason	1958	250	Bellrose (unpublished)					
Stewart Lake (upper point)	Mason	1962	0	Bellrose (unpublished)	...	...	0	0	0
Sanganois	Cass	1969	P	Bellrose (unpublished)					
Sanganois	Cass	1970	P	Bellrose (unpublished)	...	...	0	0	0
Lake Meredosia	Cass	1958	90	Bellrose (unpublished)					
Lake Meredosia	Cass	1962	100	Bellrose (unpublished)					
Lake Meredosia	Cass	1964	150	Bellrose (unpublished)					
Lake Meredosia	Cass	1967	115	Bellrose (unpublished)	P	0	0	0	0
Nutwood	Calhoun				...	...	30	10	0
Areas Other Than Mississippi and Illinois Rivers									
Beloit, Sugar River	Winnebago	1965	12	Mrs. Ed Laechelt (unpublished)	...	...	...	...	0
Roscoe, Kinnikinuck Creek	Winnebago-Boone	?	P	J. Oar (unpublished)					
Rockford, Kishwaukee River	Winnebago	1947	29	DuMont (1947*b*)					
Rockford, Kishwaukee River	Winnebago	1959	34	Mumford (1959)					
Cherry Valley, Kishwaukee River	Winnebago	1958	25	Johnson (unpublished)					
Cherry Valley, Kishwaukee River	Winnebago	About 1967	P	J. Oar (unpublished)	...	...	...	...	0
Lindenwood, Killbuck Creek	Ogle			C. Swanson (unpublished)	...	...	...	...	P
Belvidere, Piscasaw Creek, Kishwaukee River	Boone	1966 or 1967	30	J. Oar (unpublished)	...	...	...	...	0
Chemung, Piscasaw Creek	McHenry			C. D. Hudson (unpublished)	...	...	...	...	P
Hartland, Kishwaukee River	McHenry	1964–1967	P (4 years)	Fawks (1967*b*)					
Antioch (north in adjacent Wisconsin)	Kenosha	1956	17	Williams (1957)					
McHenry, Fox River	McHenry	1957	1	Fawks (1967*b*)					
McHenry, Fox River	McHenry	1967	30	Fawks (1967*b*)	...	...	...	...	0
Barrington, Fox River	Lake-Cook	1949	1	Ford (1956)					
Half Day, Des Plaines River	Lake	1932	20	Ford et al. (1934)					

(Table 1 continued on next page.)

TABLE 1.—Continued

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
Upper Des Plaines River	Lake	1932	15	Ford (1932)					
Upper Des Plaines River	Lake	1933	14	Sanborn (1935*b*), Ford (1956)					
Upper Des Plaines River	Lake	1934	25	Sanborn (1935*b*)					
Upper Des Plaines River	Lake	1935	38	Sanborn (1935*b*)					
Upper Des Plaines River	Lake	1941	22	Smith (1941)					
Upper Des Plaines River	Lake	1949	8	Ford (1956)	...	...	...	...	0
Wheeling, Des Plaines River	Cook	1889	P	Gault (unpublished)	...	...	...	...	0
River Forest, Des Plaines River	Cook	1888	P	Gault (unpublished)	...	...	...	...	0
Deerfield, Chicago River	Lake	1899	14	Gault (unpublished)	...	...	...	...	0
Jackson Park, Lake Michigan	Cook	About 1940	1	Nice (1952)					
Orland Park, Des Plaines River	Cook	?	P	Coursen (1947)					
Willow Slough, Indiana	Newton	1953	P	Nolan (1954*b*)					
Willow Slough, Indiana	Newton	1959	0	Mumford (unpublished)					
Funks Grove, Timber Creek	McLean	1951	3	Calef (1953)					
Urbana, Salt Fork	Champaign	1958	1	Kendeigh & West (1958)					
Philo, Embarras River	Champaign	1897	P	Hess (1910)	...	...	...	...	0
Lake Springfield, Sangamon River	Sangamon	?	P	Eifert (1949)					
Brouilletts Creek, Wabash River	Edgar	About 1971	10	C. Foley (unpublished)	0	...	...	0	...
Hutton, Ind., Wabash River	Vigo				...	...	...	20	...
Mt. Carmel, Wabash River	?	1875?	P	Nelson (1877)					
East Mt. Carmel, Ind., White River	Knox				...	...	...	7	0
Hovey Lake, Ind., Wabash & Ohio rivers	Posey	1950	100	Skaar (1951)	...	...	...	0	...
Equality, Saline River	Saline				6	4	1	0	...
Little Lusk Creek, Lusk Creek	Pope	1957	5	J. Schwegman (unpublished)					
Little Lusk Creek, Lusk Creek	Pope	By 1960	0	J. Schwegman (unpublished)					
Flick Branch, Lusk Creek	Pope	1967	6						
Flick Branch, Lusk Creek	Pope	1970	0						
Golconda, Lusk Creek	Pope	1946	P	L. Maedeker (unpublished)					
Golconda, Lusk Creek	Pope	1969	33	J. Schwegman (unpublished)	30	35	20	20	0
Grantsburg, Bay Creek	Johnson	1966	P	J. Schwegman (unpublished)	0	0	0	0	...
Grantsburg, Bay Creek	Johnson	1969	0	J. Schwegman (unpublished)					
Grantsburg No. 2, Bay Creek	Johnson				...	0	10	45	45
West Vienna, Cache River	Johnson	1969	P	J. Schwegman (unpublished)	...	...	P	15	P
Heron Pond, Forman, Cache River	Johnson	1954	P	J. Schwegman (unpublished)					
Heron Pond, Forman, Cache River	Johnson	1969	54	J. Schwegman (unpublished)	70	0	0	0	...
Unionville, Ohio River	Massac	1950's	P	J. Schwegman (unpublished)					
Unionville, Ohio River	Massac	1966	15	J. Schwegman (unpublished)					
Unionville No. 2, Ohio River	Massac	1968	6	J. Schwegman (unpublished)	P	100	80	40	35
Shobonier, Kaskaskia River	Fayette				135	70	20	10	15
Upper Carlyle Reservoir	Fayette	1972	56	M. McHenry (unpublished)	0	0	0	0	...
Crooked Creek, Kaskaskia River	Clinton				120	80	20	15	...
Rend Lake	Jefferson				15	25	30	15	...
Crab Orchard Lake, Little Grassy Creek	Williamson	1945	P	Bennett (1953)					
Crab Orchard Lake, Little Grassy Creek	Williamson	1948	134	Lopinot (1950)					

(Table 1 continued on next page.)

TABLE 1.—Continued

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
Crab Orchard Lake, Little Grassy Creek	Williamson	1949	110	Lopinot (1950)					
Crab Orchard Lake, Little Grassy Creek	Williamson	1950	76	Lopinot (1950)					
Crab Orchard Lake, Little Grassy Creek	Williamson	1951	59	Bennett (1953)					
Crab Orchard Lake, Little Grassy Creek	Williamson	1952	36	Bennett (1953)	...	...	...	...	0
Number of nests counted, 1973–1976					929	1,004	1,053	770	...
Number of colonies in which great blue herons were counted (excludes colonies counted but once)					16	22	26	26	...
Colonies not censused in year indicated					10	4	0	1	...
Estimated number of nests uncounted (highest available count of closest year)					505	263	0	95	...
Estimated total number of nests (to nearest 5)					1,435	1,265	1,055	865	...

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[a] Counts above 5 rounded to nearest 5 (our data only).

[b] Nests present but not counted.

[c] Number calculated from author's data.

(1975). The 25 colonies that we censused each year between 1974 and 1976 showed a decline of 39 percent (Table 1). Though nearly every colony declined some, the Savanna Depot and Sabula colonies in northwestern Illinois appeared to be the most stable, while southern Illinois colonies declined much more (64 percent, 1974–1976). In Table 1 we have attempted to estimate the statewide population of great blue heron nests from 1973 to 1976, using for the counts that we lacked data from the counts made closest in time. The annual figures indicate a progressive loss of 12–18 percent per year. Such a progressive change is unexpected. Bellrose (*in* Mills et al. 1966) found the number of great blue heron nests in the middle Illinois valley to be extremely variable—775 in 1958, 1,140 in 1962, and 385 in 1964. The same area produced about 235 nests in 1973–1974, and 190 in 1975–1976, i.e., it showed the same trend as did the entire state.

The causes of the declines cannot be determined precisely without more detailed study on the ecology of the birds. Human activity could hardly be more destructive to heron populations if that were the goal. Agricultural pursuits cause complete deforestation of large areas as well as the draining of the herons' foraging areas. Foresters, who make a practice of cutting the largest trees, effectively select against the great blue, which nests selectively in the largest trees. The cutting of heronry sites has been recorded by Barnes (1927) in Marshall County, Bjorklund (1975) in Tazewell County, Schwegman (unpublished 1969) in Massac County, and by us (1976) in Union County. Flooding, which kills the nest trees, also ultimately eliminates the colony site (Barnes 1909). Deane (1897), Strode (1917), Musselman (1926), Angus (1937), and Jenkins (1942) reported colonies being "shot up," and some ignorant people still pursue this practice though it is strictly illegal. At the Lusk Creek heronry in 1973 we found cartridge cases and dead young. Such shooting may cause the abandonment of the heronry (Strode 1917, Musselman 1926), but colonies sometimes survive (Mumford 1959), an indication of the birds' tenacity in remaining at a good site. Colonies on the upper Kankakee drainage survived for years even though they were exploited by plume hunters (Deane 1897).

Besides deliberate vandalism, other human disturbance may be important. Herons require relatively undisturbed fishing as well as nesting areas, and the human populace flocks to the waterways in summer, when the demand for food for the young herons is greatest. Human intrusion at colonies also causes the young to lose food through their action of disgorging when the colony is disturbed (Harlan 1943).

Destruction of great blue heron nests by windstorms is apparently not uncommon (Bartel 1934*b*, Bennett 1953, Nolan 1958*b*), the weight of the large

TABLE 2.—Nest trees of great blue herons in Illinois.

Species	Number Identified	Percent	Tree Size (DBH in cm)			Nest Height in Meters		
			Number	Range	Mean	Number	Range	Mean
Silver maple *(Acer saccharinum)*	64	20.5	32	38–147	66	12	17–23	20
Sycamore *(Platanus occidentalis)*	49	15.7	25	61–157	86	43	17–27	22
Cottonwood *(Populus deltoides)*	48	15.4	10	48– 94	63	6	21–29	25
Dead trees, mainly elms *(Ulmus)*	42	13.5	8	38–102	63	18	14–20	17
Bald cypress *(Taxodium distichum)*	34	10.9	17	33–135	66	13	18–27	23
Tupelo gum *(Nyssa aquatica)*	32	10.3	29	25–122	58	47	15–29	23
Oaks *(Quercus palustris, Q. lyrata, Q. macrocarpa)*	18	5.8	2	48– 84	66	3	17–20	18
Black willow *(Salix nigra)*	9	2.9	9	38– 58	46	9	15–23	18
Green ash *(Fraxinus pennsylvanica)*	5	1.6	2	43– 58	51	1	...	18
Honey locust *(Gleditsia triacanthos)*	4	1.3	3	33– 71	46	5	18–21	19
Swamp cottonwood *(Populus heterophylla)*	2	0.6	2	36– 51	43	2	18–21	20
River birch *(Betula nigra)*	2	0.6	..	...	..	..	...	..
Hickory *(Carya sp.)*	2	0.6	1	...	58	1	...	20
Box elder *(Acer negundo)*	1	0.3	1	...	56	2	14–15	14
Total	*312*	*100.0*	*141*			*162*		
Mean of means					*66*			*21*

nests probably being a contributing factor, but no instance of colony abandonment has been recorded because of wind. Strangely, the weight of great blue nests has not been measured. A windstorm in late June 1974 did extensive damage to colonies in northwestern Illinois. About one-fourth of the nests were destroyed at East Dubuque and New Boston and over one-third at Sabula, killing the young birds, which were more than half grown. The Sabula colony was also decimated by wind in 1943 (Harlan 1943). Wind protection may be a factor in the location of colonies within extensive tracts of timber. Of the 24 colonies we visited, 1973–1975, 9 had obviously lost nests to windstorms.

There are few data relating to the effects of pollution on great blue heron populations in Illinois. A moribund great blue found near Harvard in June 1977 contained high levels of organochlorine residues—12 ppm of dieldrin in the brain (Andrea Kane unpublished). Our preliminary data on eggshell thickness suggest that herons may be victims of hydrocarbon pollution. We took 5–10 measurements of shell thickness on each of 11 great blue heron eggs from two colonies (Clarksville, which had great blues only, and Hamburg, which had great blues and great egrets) on the Mississippi River (see introduction). The shells appeared to be from hatched eggs. The range of shell thickness (62 measurements) was 244–360 microns, with an overall mean of 312 (SE = 3.60). The average shell thickness at Hamburg was 330 microns (SE = 3.0), and at Clarksville, 302 (SE = 4.57). Average shell thickness for pre-1947 eggs of great blues, presented by Faber et al. (1972), was 396 microns. The Illinois eggs were also thinner than recently hatched or broken eggs of California birds (range of means: 328–365, Faber et al. 1972). Within the same cross-sectional perimeter of an egg, we found shell thickness to be very constant (range: 331–334 microns, mean: 332.2, SE: 0.49), but thickness varied much more along the length of a different egg (range: 274–309 microns, mean: 292.7, SE: 4.93). The pre-1947 eggs were probably oological specimens and probably mainly fresh specimens, as oologists consciously tried to get fresh eggs. We would expect fresh eggs to have thicker shells than hatched eggs due to wear and absorption. The amount of loss in shell thickness during incubation is apparently unknown, but needs to be determined before the full extent of shell loss from pollution can be determined. A special study is needed on the whole problem of shell thinning and productivity in Illinois herons.

If we are to conserve the remnant nesting population of great blues in Illinois, every effort should be made to protect both the colony sites and the fishing areas, even to the point of eliminating human traffic in those areas during the breeding and migration seasons. It is important to locate the major fishing areas for each colony. The problem of determining population trends of the herons is the problem of conducting studies that are both intensive and extensive in terms of area (hundreds of square miles) and time (20 years or more). The natural oscillations of any population are generally unknown, and the abandonment of a colony site cannot be assumed to be either a change of nesting locale or a population loss.

Nesting Cycle

If any type of "song" accompanies courtship of Illinois great blue herons, it has not been described. The only calls we have heard are the loud, raucous, croaking notes of birds disturbed at their fishing grounds, or colony, and the begging noises of the young. Upon arrival from the winter range, great blues go almost immediately to the nesting colony. Arrival dates at the colony are as early as arrival dates to the area (Smith 1942*a*, Sanborn 1943*a*, Lopinot 1950, Brown 1974). Yearling birds are not believed to breed (Bent 1926), but there are no Illinois data on the question of where these birds go or what they do. Much of what is known about the nesting cycle of the great blue in Illinois comes from the study of Lopinot (1950) at the Crab Orchard Lake heronry. He observed interesting courtship displays, involving mutual preening by the paired birds, and copulation at or near the nests, which ranged in height from 12 to 18 m. Many of the nests, large stick structures, are reused and added to each year (Barnes 1909). At Crab Orchard both members of the pair brought sticks to the nest, and old nests (of previous years) were the first sites to be occupied. At Sabula great blues were building on 26 March (Anonymous 1977). Four fallen but reasonably intact nests which we measured at East Dubuque and Carlyle Lake averaged 81 cm in diameter by 36 cm deep (outside). The time requirement for nest construction, or reconstruction, has not been recorded, but Lopinot's (1950) study indicated a time lapse of nearly a month between the arrival of the birds to the colony and the onset of laying. Distribution of nests varies from one per tree to as many as 32 per tree (the highest number we have seen) with intermediate observations of 9, 11, and 19 per tree (Nelson 1877, Angus 1937, Barnes 1909). Angus (1937) considered two to five nests to be the usual number.

At Crab Orchard a great blue first began sitting on its nest on 18 March, but Lopinot did not see the first egg until 25 March. Near Pekin, Bjorklund (unpublished) recovered a great blue egg as early as 21 March. Precise laying dates are not available for any other colony, but Musselman (1933) reported great blue eggs hatching by 2 May, indicating egg laying by about 4 April near Quincy. At Lake Forest, Smith (1941) recorded fledging of young by 5 July, indicating laying by about 15 April. Also in the north Barnes (1909) reported fresh eggs 2–6 May. Although the span of egg laying for most nests within a colony may be relatively short (i.e., about 10 days, according to Lopinot's observations), not all nests are so closely synchronized in laying, and annual variation also expands the laying season. Thus, 1973 appeared to be a late year for some colonies, and 1975, early. Judging from early egg dates and the latest dates when we've observed fledging, the egg laying season for great blues in Illinois extends from about 25 March to 17 May.

The eggs are unmarked, pale blue or greenish. There are no very recent data on clutch size. Fourteen sets of eggs collected in the last century in northern and central Illinois by R. M. Barnes and Isaac Hess had the following distribution of clutches: 6 eggs—two sets, 5 eggs—six, and 4 eggs—six. Elsewhere, Barnes (1909) stated that clutches ranged from 3 to 6 eggs. At Crab Orchard, Lopinot (1950) observed that most nests received 4 eggs, some 3. It is apparently unknown whether eggs are laid on consecutive days. Lopinot (1950) observed a great blue sitting on its nest even before the eggs were laid, and incubation probably starts with the first egg. Both adults incubated the eggs, and the exchange of birds on the nest took place "several times" during the day.

Lopinot (1950) found the incubation period to be 29 days from the laying of the first egg on 25 March to the hatching of the first young on 23 April. This observation is in close agreement with the figure (28 days) given by Bent (1926). At a Lake County heronry, Gault (unpublished 1889) observed herons standing on branches near the nests while their presumed mates incubated the eggs.

Lopinot observed that the young were brooded for about a week after hatching and that both adults brought food to the nest, the first food being very small fish about 5 cm in length. When they brought food, the adults engaged in a kind of pumping action of the throat to bring the food up, then regurgitated several fish at a time into the nest. The adults cast up fish two to three times during a visit, then sometimes reingested food that the young did not eat. Feeding rates were highest at about 6 a.m. and 5 p.m. Especially when adults bring food, the young can be very noisy, uttering a kind of gabbling sound that makes a colony audible a kilometer away.

At 3 weeks of age, the young stand erect in the nest, and at about 5 weeks they begin to walk about on the limbs of the nest tree. At 7 weeks they begin to fly short distances. Lopinot (1950) first observed regurgitation by the young, as a reaction to disturbance, at about 6 weeks of age.

Scattered observations indicate the progression of the nesting cycle. Lopinot (1950) observed that most great blues, adults as well as young, had left the Crab Orchard colony by 11 July. In central Illinois, Musselman (1933) reported young crawling out of the nest on 9 June 1932. In northern Illinois young great blues have been reported able to stand in the nest by 12 May (Barnes 1927), not quite ready to fledge by 17 June (Bartel 1934*a*), ready to fledge by 18 June (Ford et al. 1934), and mostly fledged by 26 June with a few still present in nests in mid-July (Ford 1932 and 1956). We have seen a few young still in nests as late as 1 August (1973) in both northern and southern Illinois.

Our counts of young indicate a somewhat later ending of the cycle than the above observations (Table 3), with about one-half of southern Illinois nests fledged by 5 July and nearly three-fourths by 16 July, while in northern Illinois about two-thirds of the nests were fledged by 22 July. Many of our data were collected in 1973, a year in which nesting appeared to be late, possibly because of unprecedentedly high flooding in the Mississippi Valley.

There are no published data on nesting success or productivity for any great blue heron colony in Illinois. Such data are difficult to acquire, the nests be-

TABLE 3.—Number of great blue heron nests with young, by date of observation.

Region of Illinois and Date	Nests with 1 Young	Percent with 1	Nests with 2 Young	Percent with 2	Nests with 3 Young	Percent with 3	Nests with 4 Young	Percent with 4	Total Young	Total Nests with Young	Young per Occupied Nest	Percent of Nests Vacated
					North and Central							
29 June–10 July	15	30.0	15	30.0	8	16.0	12	24.0	117	50	2.3	
14–15 July	16	53.3	9	30.0	5	16.7	0	0	49	30	1.6	36.2
22 July	11	61.1	3	16.7	2	11.1	2	11.1	31	18	1.7	62.3
Total or mean									*197*	*98*	*2.0*	
					South							
20 May–23 June	10	25.0	10	25.0	9	22.5	11	27.5	101	40	2.5	
1–5 July	8	29.6	10	37.0	7	25.9	2	7.4	57	27	2.1	42.5
9–10 July	8	40.0	5	25.0	4	20.0	3	15.0	42	20	2.1	
16 July	10	62.5	2	12.5	4	25.0	0	0	26	16	1.6	72.4
Total or mean									*226*	*103*	*2.2*	

ing hard to reach for the purpose of determining clutch size and hatching and fledging success. Also, fairly continuous surveillance is needed to determine accurately the number of young fledged. Precise data on productivity are badly needed to interpret population changes (see below under Mortality). During our censuses of colonies we made counts of large young per nest (Table 3). However, such counts are not a true measure of productivity, as they err on the one side by not including nesting attempts that produced no young or nests that failed after our visit, and on the other by missing young that fledged before our visit. It can be seen (Table 3) that our highest average counts—2.3 young per nest in north and central Illinois and 2.5 per nest in southern Illinois—were observed relatively early in July or in June and declined as the weeks passed. The decline probably represented the fledging (or mortality) of young. These figures exclude nests in which we could see no young. Coincidentally, the number of empty nests and nests with one young increased as the number with three and four young declined. DuMont (1947*b*) reported that 29 nests in the Rockford area averaged three young per nest, but their ages were not stated.

Causes of nest failure, other than human vandals and the windstorms noted above, are generally unknown. We saw no evidence of renesting following the severe wind damage of 1974. Bjorklund (1975) suspected that nesting success declined at the Pekin colony as the area was opened up by timber cutters. Great blue herons are formidible adversaries for would-be predators. Musselman (1933) observed great blues repulse an apparent attack on a heron colony by a bald eagle, and we have witnessed a similar event involving a red-tailed hawk. Horned owls sometimes nest in great blue heron colonies (Lopinot 1950, Bjorklund et al. 1967) and may prey upon the herons, but the actual effect on either species is unknown. We have seen both turkey and black vultures at heron colonies, often perched in the nest trees, but their effect on the colony, if any, is unknown (see also Greer 1955). Lopinot (1950) observed a raccoon feeding on a young heron in a nest, but this may have been a case of carrion feeding. In *Ardea cinerea,* Owen (1959–1960) found that starvation was a common cause of mortality and that the youngest birds of the brood were most likely to succumb. Because incubation starts with the first egg, the ages of the nestlings are staggered.

The only Illinois reference we have found on diseases or parasites is that of Shoop (1931) on an infestation of the fluke, *Clinostomum,* in one specimen.

Fall Migration

Following the nesting season, at least some great blue herons move northward before migrating south. Bartel's (1937 and 1976) banding studies once again provide especially fine data on the movements of a species. Apparently no adult great blues have been banded in Illinois. Recoveries of young great blues that Bartel banded at the Depue colony in June and July from 1933 to 1939 show the northward dispersal in late summer and fall (Fig. 6). Of the 29 recoveries of immatures, 10 were from localities (Wisconsin and northern Illinois) north of the colony. Six of these recoveries were obtained in the same year as banding, and their dates ranged from 18 July to 19 October (one indirect recovery in the north was as late as 26 October), but most of these northern recoveries came in July and August. Five recoveries were from near the colony site. Thirteen of the recoveries were from latitudes south of the colony. Five of these birds were recovered in the same year as banding on dates from 19 September to 30 November. Only one midsummer (29 July) recovery was made south of the colony, and that barely south (Rensselaer, Indiana). These records show a pattern of northward dispersal in July and August, after the nesting season, with some birds lingering in the north even late in October. The southward migration occurs in September and October, coinciding with the

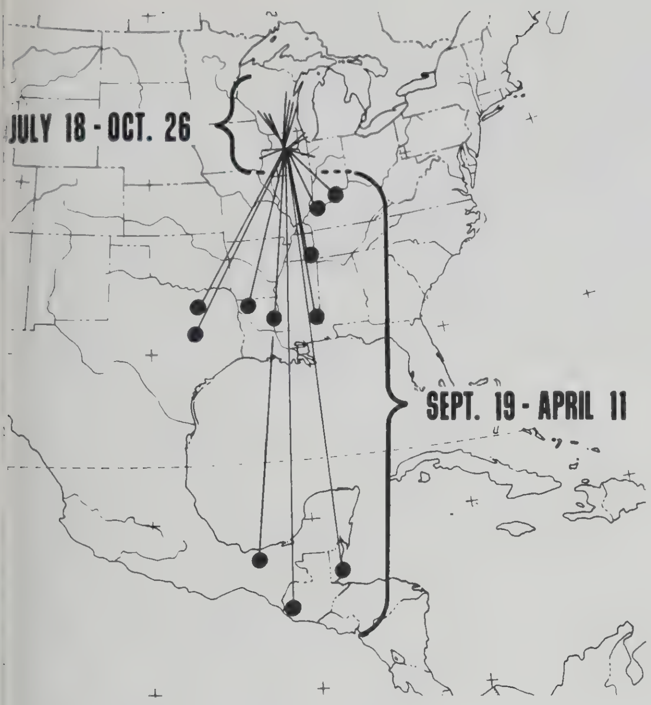

Fig. 6.—Direct and indirect recoveries of great blue herons banded as nestlings in Illinois, with months of recovery north and south of the state indicated.

regular seasonal decline (Fig. 3). Bjorklund & Canterbury (1971) record a recovery from Tabasco, Mexico, by 1 November.

Though the orientation of the late summer flights is widely spread from east-northeast to west-northwest, the virtual absence of July-August recoveries from south of the colony implies that these early flights have a definite orientation northward, rather than to all points of the compass. The sample, however, is small though it represents a large amount of work (at least 445 great blue herons banded). Little else is known of the northward flights in fall—what stimulates them, whether they are made in short hops or one long diurnal (nocturnal?) flight, whether a given population has a specific orientation, and other details. The most northern recovery from Bartel's (1935 and 1976) studies was about 434 km from the banding site (Fig. 6).

What brings the birds back to southward orientation is unknown. Angus (1937) observed what was apparently the onset of a southward migration along the Mississippi River near sunset on 22 October 1935. The birds flew in eight small flocks of 2–16 birds each in V or line formation, calling as they went. These migrating birds appeared to stimulate great blues on the ground to rise and join the flight. Musselman (1937) also refers to great blues migrating southward in V formation on 26 August, the earliest observation of actual fall migration. Angus's (1937) reference to a departure of great blues at sunset is revealing also as an indication of nocturnal migration, as is a specimen killed at a television tower near Orion, Illinois, on the night of 6–7 October 1959 (Petersen 1959). We heard great blues flying and calling on the night of 18–19 October 1959 at 11:15 p.m. and 2:05 a.m. CST at Havana.

Although most of the great blue heron population has left Illinois by the end of October (Fig. 3), in some years a few birds may linger even in the north well into November and even December (Work 1934–1935, Boulton & Beecher 1940, Nelson 1876–1877, Balch 1972). Coursen (1947) observed that few birds remain at Orland until the marshes freeze. On the Illinois and Mississippi rivers as many as 150 great blues have been seen in early December (Mumford 1960*b*) and 29 were seen on 30 December (Hamilton 1968), but such late concentrations are unusual. They presumably represent the winter population. The source of these late birds is unknown.

We have found but one reference to the late summer-fall roosting behavior of great blues. Franzen (1934) observed 40 or more that regularly visited Lake Calumet in late August and left (consistently) about 5 p.m., flying southwestward, presumably to a roost. The nature of the roost was unknown.

The peak in fall numbers of great blue herons appears to come between 1 August and 20 September in southern Illinois, and 16 August–20 September in central and northern Illinois (Fig. 3). The fall numbers are too large to represent only Illinois production. The ratio of spring to fall counts of great blues was 1:3.05 for the entire state (1967–1970), 1:3.8 for southern Illinois (1967, 1970), and 1:4.7 for central Illinois (1969), but only 1:1.3 for northern Illinois (1968). Whether the low ratio for the north represents regional or annual variation is unknown. The best possible age ratio deducible from our data on productivity (Table 3) would be 1 adult:1.25 juveniles (based on 2.5 young per nest). Excluding (yearling?) non-breeders, this ratio falls far short of the 1:3 fall ratio observed for the state, and much of the fall count may represent immigration from more southern breeding populations.

Winter Records

Most great blue herons have left Illinois by the end of October (Fig. 3). Birds present in November and December may be late stragglers attracted to open water and good fishing areas, but the sources of these birds and their seasonal status are unknown. The Christmas counts show that at least a few great blues are present even in northern Illinois in most years (Fig. 7 and 8). They are much more frequent in southern Illinois. There is a highly significant correlation ($r = 0.596$, $P = 0.001$) between the frequency of occurrence of great blues on the Christmas counts and the average December temperature in northern, central, and southern Illinois. The frequency in-

Great Blue Heron

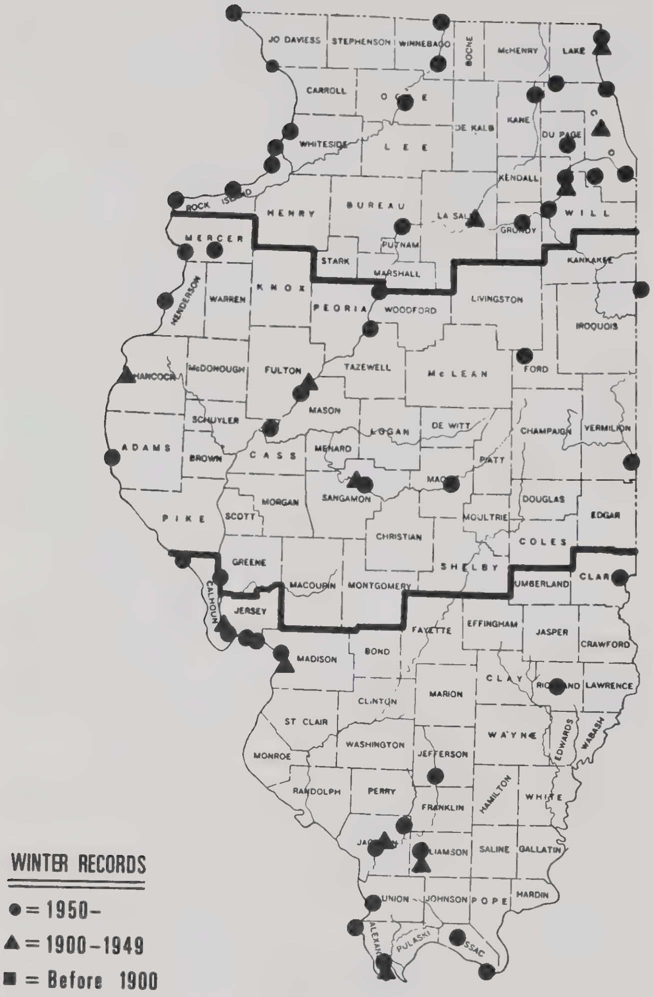

Fig. 7.—Distribution of winter (15 December–1 February) records of the great blue heron in Illinois. Heavy horizontal lines separate the three regions referred to in the text.

creases at temperatures above about −1° C. There is no significant correlation between the occurrence of great blues and temperatures in November or January. Of the three regions, only southern Illinois has long-term average temperatures above −1°C in both December (about 2° C) and January (about 1° C), and great blues may be expected there throughout the winter but only in small numbers. As open waters in northern and central Illinois freeze up, the number of herons probably declines, but population measurements have not been made beyond the Christmas count period (about 2 January). Michael Morrison noted that great blues did not remain even in southern Illinois during the severe winter of 1976–1977.

Nothing is recorded on the winter ecology of the species.

Food

Most of the data on food of great blue herons in Illinois represents regurgitated food of nestlings (Table 4). Whether adults eat approximately the same things is unknown. Even the data for nestlings may be biased if the young tend to cast up certain foods more than others. The samples we gathered at 12 colonies around the state (see introduction) indicate that two species—gizzard shad and carp—comprise over half the food of young great blues. Four groups of fishes—shad, carp, buffalos, and sunfishes—make up about 80 percent of the food. One or more of these food species have also been reported by Musselman (1933, 1934–1935), Angus (1937), Harlan (1943), Hodges (1950), and Lopinot (1950). In addition to the prey species listed in Table 4, "catfish," "mud-eel" *(Siren)*, "frogs," and "snake" have been reported as food of great blues in Illinois. The only data on the food of an adult great blue is that recorded by Lopinot (1950), who found a 7-inch white crappie in the stomach of one specimen. All species listed in Table 4 have generally high populations in Illinois.

Besides the need for data on the seasonal and geographic variation in the food of adults (especially), there is need for studies on feeding rates and feeding areas of great blues and other herons in Illinois. Lopinot (1950) observed that the size of food items increased as the young grew. We have measured carp as long as 30 cm from nests with very large young (see also Hodges 1950).

Food for the colony may be taken nearby. We have observed great blues from the Lusk Creek colony foraging in Lusk Creek, but have also seen them

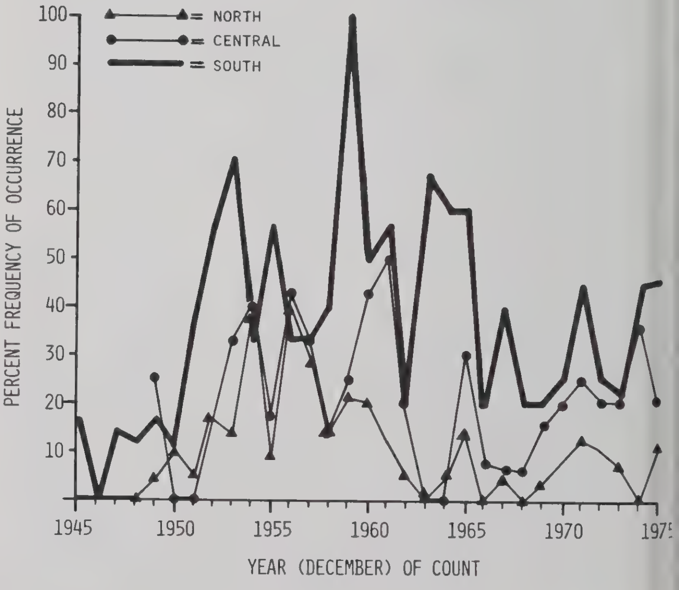

Fig. 8.—Frequency of occurrence of great blue herons on Christmas counts in the three regions of Illinois.

TABLE 4.—Food collected from nestling great blue herons at Illinois heron colonies, 23 June–1 August 1973–1977.

Food Item	Number of Specimens				Total Specimens	Percent of Total	Estimated Weight of Food (Grams)	Percent of Weight
	Illinois River	Upper[a] Mississippi River	Lower[b] Mississippi River	Ohio River Drainage				
Crayfish *(Orconectes virilis)*	0	1	1	0	2	0.4	?	?
Longnose gar *(Lepisosteus osseus)*	0	0	1	0	1	0.2	30	0.2
Shortnose gar *(L. platostomus)*	0	0	3	0	3	0.5	120	0.9
Gar *(Lepisosteus* species?)	0	0	3	2	5	0.9	200	1.5
Bowfin *(Amia calva)*	0	0	4	3	7	1.3	105	0.8
Gizzard shad *(Dorosoma cepedianum)*	19	35	63	94	211	38.6	4,220	31.0
Grass pickerel *(Esox americanus)*	0	0	0	2	2	0.4	30	0.2
Stoneroller *(Campostoma anomalum)*	0	1	0	0	1	0.2	3	+[c]
Goldfish *(Carassius auratus)*	0	2	0	0	2	0.4	8	0.1
Carp *(Cyprinus carpio)*	6	13	58	8	85	15.6	3,400	25.0
Golden shiner *(Notemigonus crysoleucas)*	0	0	0	11	11	2.0	22	0.2
Emerald shiner *(Notropis atherinoides)*	0	6	0	0	6	1.1	12	0.1
Red shiner *(N. lutrensis)*	0	2	0	0	2	0.4	2	+
Minnow (mainly *Notropis* species?)	0	6	0	0	6	1.1	12	0.1
Quillback *(Carpiodes cyprinus)*	0	3	0	0	3	0.5	285	2.1
White sucker *(Catostomus commersoni)*	0	5	0	0	5	0.9	375	2.8
Creek chubsucker *(Erimyzon oblongus)*	0	0	0	6	6	1.1	420	3.1
Smallmouth buffalo *(Ictiobus bubalus)*	0	1	1	2	4	0.7	100	0.7
Bigmouth buffalo *(I. cyprinellus)*	0	21	23	34	78	14.3	936	6.9
Buffalo *(Ictiobus* species?)	0	22	0	0	22	4.1	264	1.9
Northern redhorse *(Moxostoma macrolepidotum)*	0	2	0	0	2	0.4	70	0.5
Flier *(Centrarchus macropterus)*	0	0	0	2	2	0.4	16	0.1
Warmouth *(Lepomis gulosus)*	0	0	0	2	2	0.4	70	0.5
Green sunfish *(L. cyanellus)*	0	0	4	7	11	2.0	220	1.6
Pumpkinseed *(L. gibbosus)*	0	0	0	1	1	0.2	90	0.7
Bluegill *(L. macrochirus)*	0	36	5	5	46	8.4	1,380	10.1
Sunfish (species?)	0	0	0	3	3	0.5	24	0.2
Largemouth bass *(Micropterus salmoides)*	0	1	2	1	4	0.7	160	1.1
Black crappie *(Pomoxis nigromaculatus)*	0	2	0	1	3	0.5	150	1.1
Freshwater drum *(Aplodinotus grunniens)*	0	6	2	2	10	1.8	900	6.6
Total	*25*	*165*	*170*	*186*	*546*	*100.0*	*13,624*	*100.1*

[a] Mercer County and north.
[b] Pike County and south, including the Kaskaskia drainage.
[c] Less than 0.1 percent.

flying to the vicinity of the Ohio River about 10 km from the colony.

Longevity and Mortality

Between 1933 and 1949 Bartel (1976) banded 445 nestling great blue herons at the Depue colony. The 28 birds recovered from his exemplary study had an average age of about 2 years at death (four specimens captured alive were included as representing mortality). Survival was very poor in the first 6 months, with about 60 percent of the young population being lost (64 percent in the first year, Fig. 9). This mortality rate is a measure of the cost of inexperience, including a lack of wariness toward humans. Shooting was the only cause of death given, and a high loss in October and November is also indicative of hunter-vandals as the cause of mortality. After the less wary birds were killed in the first 6 months, mortality dropped to an average 24 percent per year. One bird survived 14 years, 3 months. The mortality figures are similar to those given by Owen (1959–1960) based on a much larger number of recoveries for all of Canada and the United States between 1916 and 1945. His figures were 71 percent loss in the first year and an average annual rate of 29 percent after the first year. In his larger sample, one bird survived 21 years.

There are no comparable data on mortality for more recent years to determine whether the survival rate is changing. Bartel's record represents a period when great blues were apparently thriving (see under populations), but in recent years the population has been declining about 12–18 percent per year. At the survival rate calculated by Owen (1959–1960), productivity of great blues (assuming first reproduction at about 2 years of age) would have to be 2.8 young per nest to sustain the population. The *best* productivity we observed was 2.5 young per nest, a number that

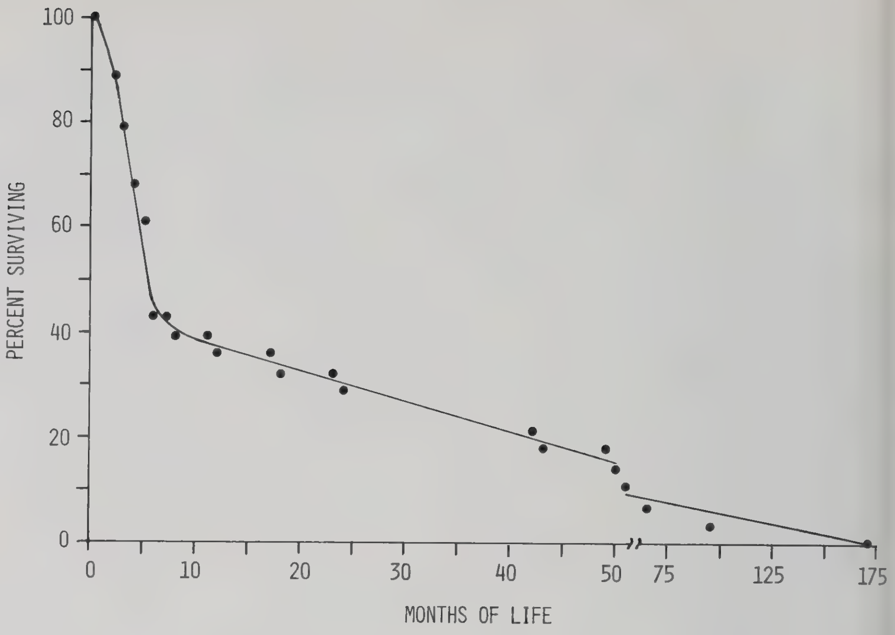

Fig. 9.—Survival of great blue herons banded as nestlings in northern Illinois. Some points represent more than one bird.

implies a loss (at the mortality rate cited) of about 3 percent per year; but our figures do not take into account broods or nests that were lost entirely.

The banding recoveries are instructive in showing why great blues seek isolation from humans. It is an isolation increasingly difficult to find, and the human pressure may already exceed what some of the Illinois populations can stand.

Specimen Data

Ridgway's (1881 and 1895) references to the occurrence of *Ardea occidentalis,* or *A. "wuerdemannii"* in Illinois probably relate to the same observation of a single bird on the Wabash River near Mt. Carmel, 11–22 September 1876. The bird, a large, white-headed great blue heron, fits the description of so-called Wuerdmann's heron, which Ridgway (1895) suggested was a hybrid between *A. occidentalis* and *A. herodias,* now considered to be conspecific (Eisenmann 1973).

Oberholser (1913) discussed specimens of *A. herodias* from southeastern Illinois and adjacent Indiana, pointing out that in their pale coloration they resembled *A. h. wardi* of the southeastern U.S., but are smaller in size.

We have weight data on only two (April) specimens—a subadult male from Fulton County (2, 268 g), and an adult female from Iroquois County (1,673 g). Both specimens were lean.

NORTHERN GREEN HERON
(Butorides striatus virescens)

(Fig. 10 and 11)

Among the recent recommendations of nomenclatural changes suggested by the American Ornithologists' Union's Committee on Classification and Nomenclature (Eisenmann 1973 and 1976) is the combining of *Butorides virescens* and *striatus* under the latter name.

Spring Migration

Green herons are generally rather late migrants, not being seen in Illinois before mid-April, with the bulk of the birds not arriving before late April and May (Fig. 12). There are at least two March records, one for southern Illinois (George 1968) and one for Cook County in 1949 (Dring unpublished), but these are very exceptional. Even early April records are unusual (Kleen 1974*e*, 1975*c*, 1976*b*). There appears to be little difference in arrival dates between the different regions of the state, possibly reflecting long-distance night migrations by the species.

In central Illinois we have heard green herons calling at night, presumably as they migrated, from 22 April to 20 May between the hours of 9:00 p.m. and 4:00 a.m. CST.

Distribution

The northern green heron *(virescens)* has a broad range in the United States and Central America (Fig. 11). In Illinois it may nest in every county, though definite records are lacking for many, possibly reflecting the paucity of observers (Fig. 13).

Nesting Habitats and Populations

Gates' (1911) designation of the green heron's primary habitat as sand or mud strand and secondarily as prairie marsh and bottomland woods is a very apt description. He implies edge habitats, especially in low-lying areas. On the cross-country censuses (Graber & Graber 1963) the two habitats in which green herons most often occurred were marsh

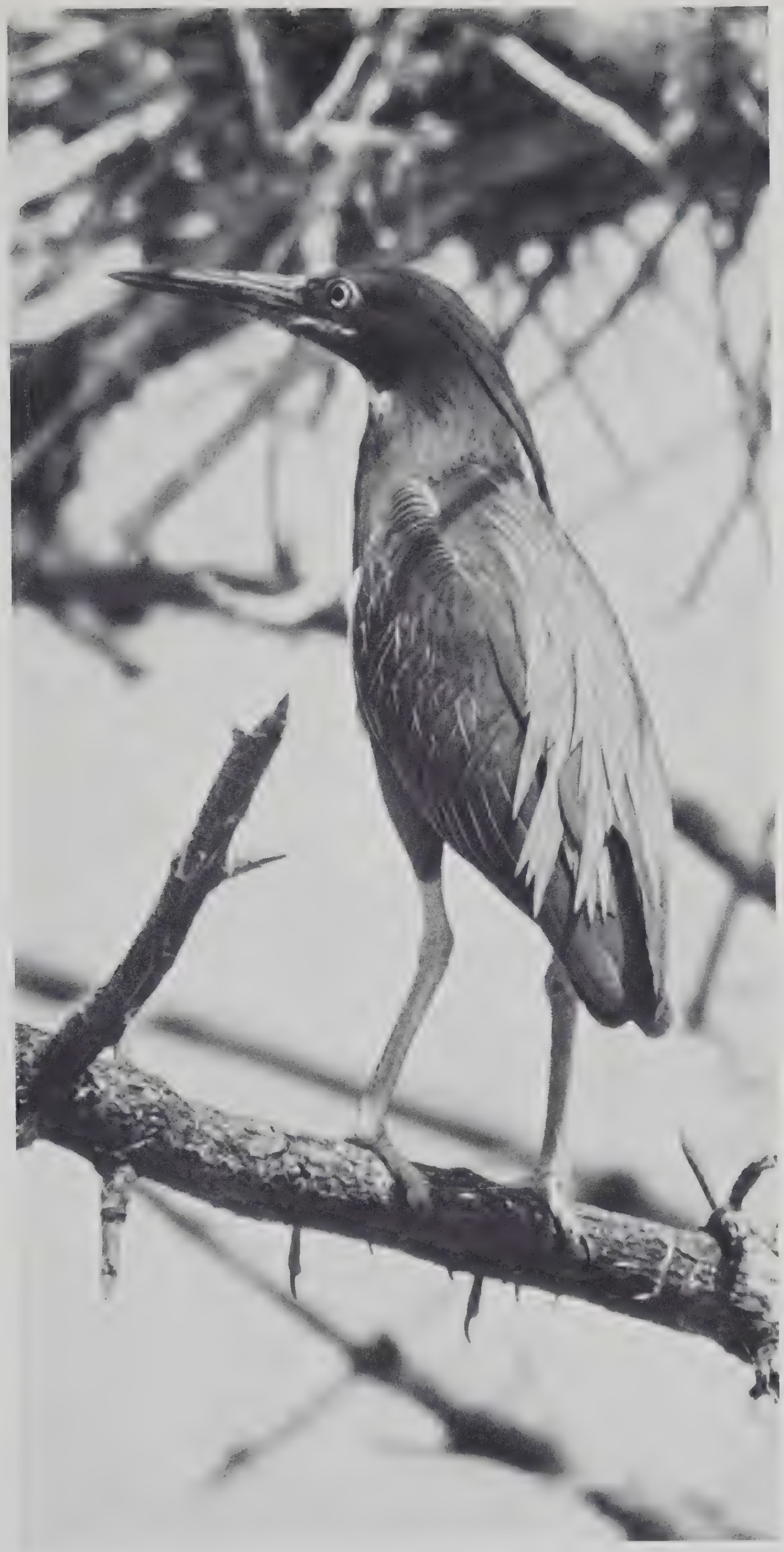

Fig. 10.—Adult green heron near its nest. The green is a relatively small heron (about 30 cm tall) with glossy, metallic green wings, and the sides of the neck rich chestnut.

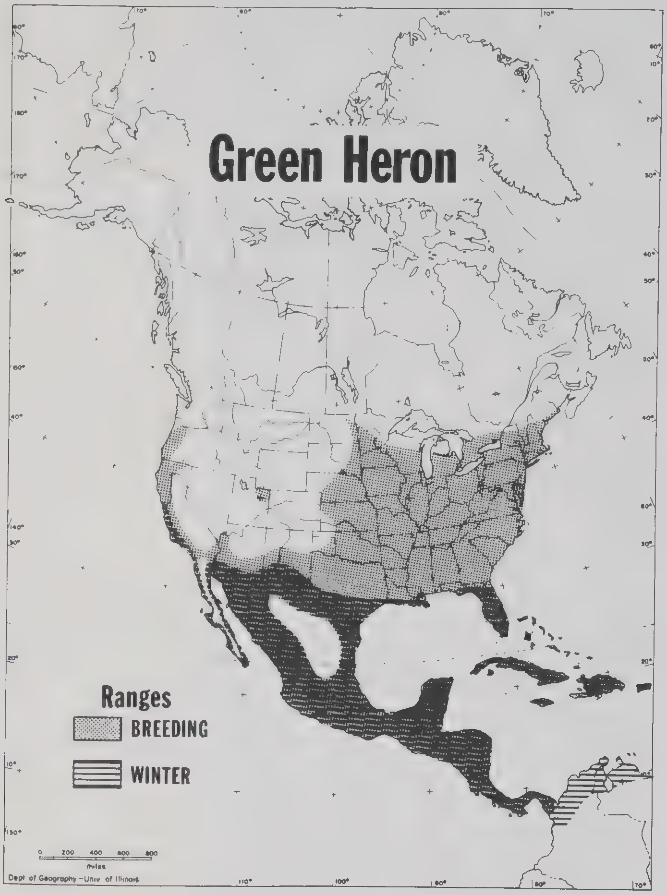

Fig. 11.—General distribution of the green heron.

and pasture, the latter especially in the early (1907–1909) censuses, when pastures often included some shrub areas and marshy spots. The population figures for forest habitat (Table 5) probably represent mainly forest edge, forest openings, or small stands. In our extensive censuses of mature forests in southern Illinois (Table 5) we have never encountered green herons in upland forest or in the interior, even of bottomland woods. Younger, less extensive, stands may have higher populations, as they seem to have in central and northern Illinois. It should be remembered that density data on small tracts of habitat are misleading and may be especially so for the green heron as an indication of the general population. The data do not account for the numerous small tracts with *no* herons, as herons have a very spotty distribution. Brewer (1958*b*) found the green heron in the 6-to-9-year-old vegetation of strip-mined land, and nests are most often reported as being in young trees.

Green herons have shown some tolerance of the human population, and Ridgway (1887 and 1925) found the species nesting in Mt. Carmel and Olney. There are, however, probably few modern urban areas with nesting green herons, and there seems little likelihood of sustaining a population in the urban habitat. In times past, at least, green herons sometimes nested in orchards (Silloway 1906, Olmstead 1906, Hess 1910, Bennett 1953), but there are no recent data on the use of this habitat.

Nesting green herons are often associated with willows (Coursen 1947), species of which are the most commonly reported nest trees. Nests have also been observed in apple, crab apple, hawthorn, buttonbush, cottonwood, balsam poplar, plum, bald cypress, and "maple" trees (Chase 1899, Hankinson 1914, Sanborn & Goelitz 1915, Jones 1936*c* and 1937*a*, Beecher 1942, Freeman 1951, Haertel 1963). Nest heights have been reported to vary from 1 to 14 m in Illinois, but are most often 2–6 m. As with herons generally, the foraging habitat of the green heron has never been defined either qualitatively or quantitatively.

Green herons nest both as isolated pairs and in colonies. Sometimes they nest with other species of herons. The colonies are usually small—fewer than 20 pairs. Yeager (1949) found four colonies in the Pere Marquette State Park area that averaged 20 nests each. Assemblages of 100 or more nests have been reported (Jones 1936*c*). Musselman (unpublished notes 1922) estimated there were as many as 500 nests in one area on Lima Lake, but no large colonies have been reported in recent years. As early as 1890 Barnes (1890*b*) believed the green heron population was declining. In 1907–1909 Gross and Ray encountered 12 green herons within the 714 km of transects through all types of summer habitats in the state. In a nearly equal length of transects (708 km) in 1957–1958, we encountered only two, indicating more than an 80-percent loss. The counts of spring migrants in central Illinois also indicate a decline. Counts of green herons made in east-central Illinois by Frank Smith and his students between 1903 and 1922 were almost invariably higher (by a factor of 2–3 times) than our counts in the same area between 1957 and 1969 (Fig. 12). All the available data indicate a serious decline in the green heron population in this century. Specific causes cannot be assigned without more detailed information on the ecology of the species. Causes almost certainly include the burgeoning human population that is: (1) destroying and polluting many habitats, including wetlands, and (2) increasing disturbance in all habitats.

Nesting Cycle

The impressive displays that accompany the courtship and mating of green herons (Palmer 1962) have not been described in the Illinois literature. The only calls we have heard from the species are the loud, sharp, single-noted "keeow" call uttered, sometimes repeatedly, at almost any time the bird flies, including night, and a kind of scolding call uttered when

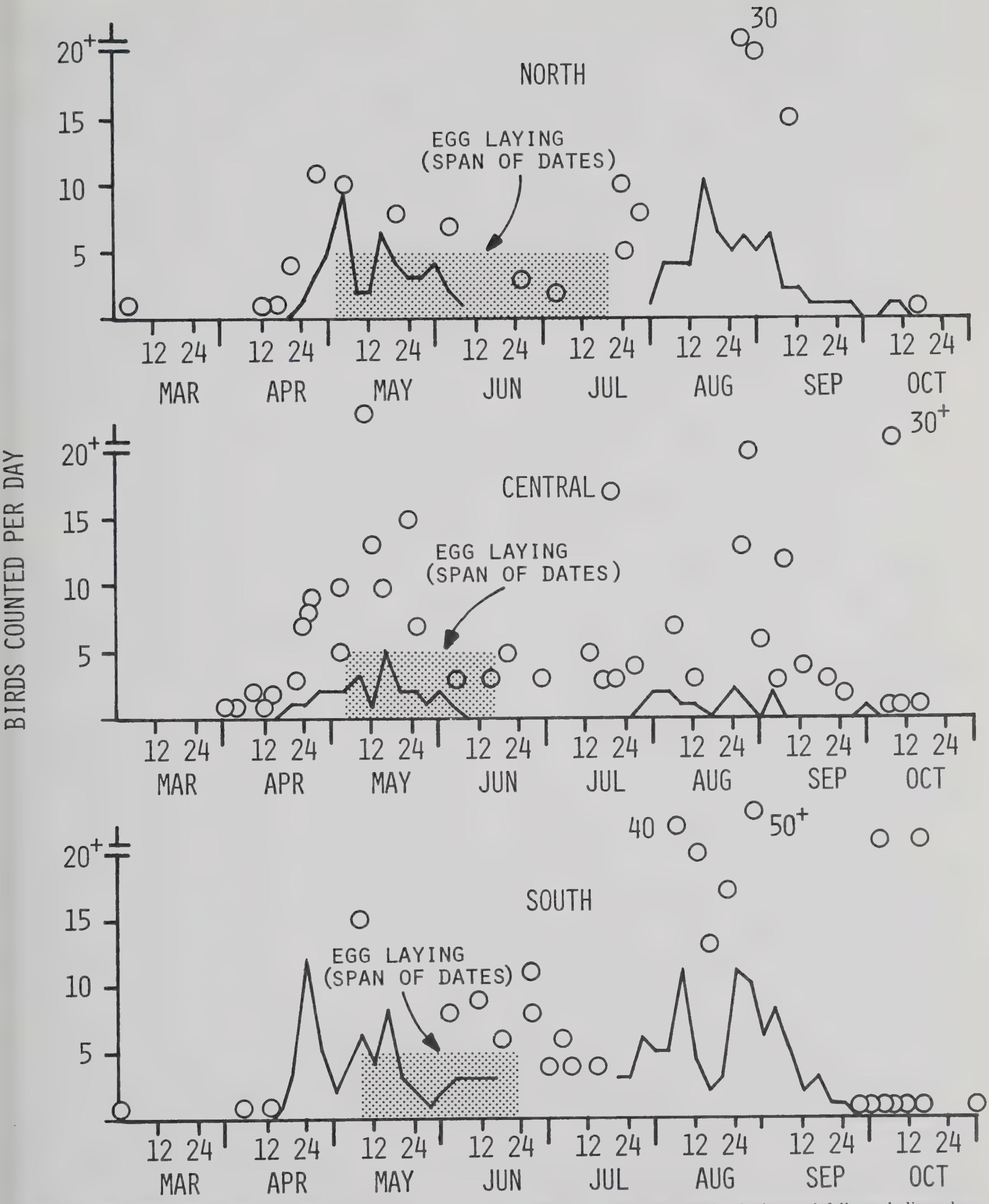

Fig. 12.—Egg-laying and migration seasons of the green heron in different regions of Illinois. Spring and fall graph lines show the highest daily count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

Green Heron

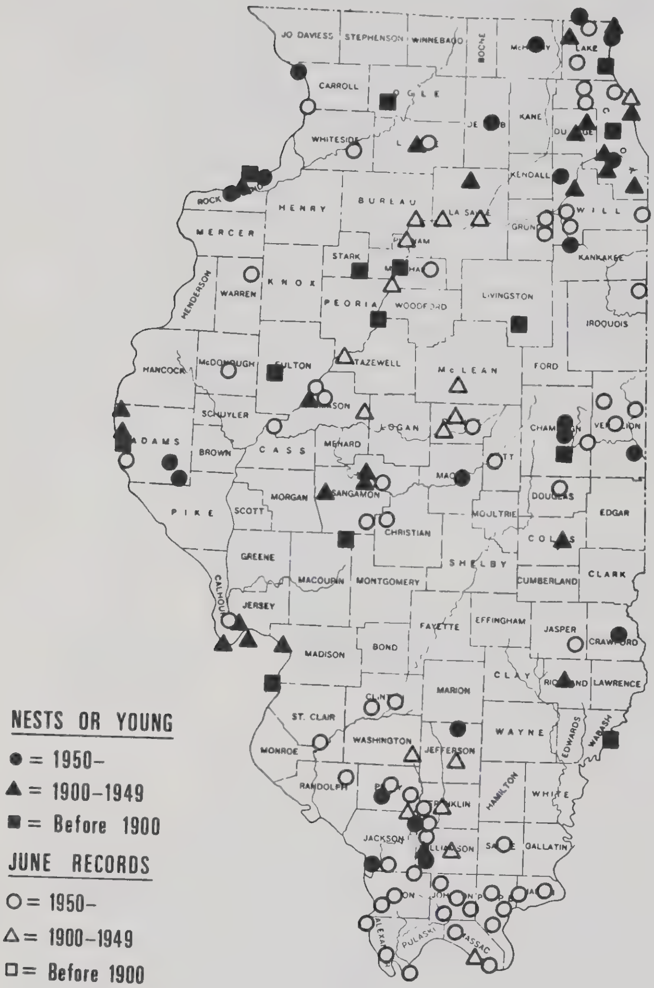

Fig. 13.—Distribution of breeding records of the green heron in Illinois.

a bird is disturbed—a series of flat "kuk-kuk-kuk" notes (Chase 1899).

Nest building has not been described, but Chase (1899) provided a uniquely detailed description of the structure of two nests in Stark County. The nests—one in a plum tree, the other in a crab apple—were made entirely of sticks of willow, plum, box elder, cherry, crab apple, and hawthorn. The number of twigs in each nest—267 in one, 265 in the other—gives some measure of the amount of work involved. The longest piece was 76 cm. Largest outside dimensions were: 33 × 43 cm (diameter), and 13 cm deep. The nest bowl was 13 × 20 cm and 5–8 cm deep.

The eggs are pale blue (Silloway 1906) or greenish blue. White (1890) stated, and gave measurements to show, that eggs of Illinois birds (location?) were larger than egg specimens from Rhode Island and Texas. There are no additional observations or explanations of these size differences. The number of eggs in each of 42 green heron clutches were: 6 eggs—three (7 percent), 5 eggs—eleven (24 percent), 4 eggs—twenty-five (56 percent), 3 eggs—four (9 percent), 2 eggs—two (4 percent). The data represent scattered, often casual, observations, made mainly in northern and central Illinois before 1920. At a colony near Vincennes, Ridgway (1882) observed that five nests out of seven had 5-egg clutches. From fresh-egg dates and hatching and fledging dates, we estimated the laying season of the green heron to extend from 2 May to 19 July in northern Illinois. The season is probably about the same for the other regions, as there appears to be little difference in the green heron's time of arrival in different regions of the state. Most of the laying dates fall between 8 May and 12 June.

Though observations are lacking for Illinois, in New York, Meyerriecks (1960) found that both sexes incubate, the incubation period being about 20 days, and that young birds make their first flights at 21–23 days of age. At least some yearling birds breed. There are no Illinois data on nesting success or productivity.

Fall Migration

If green herons move northward after the nesting season in the fashion of other herons, there are no published banding records to show it. Nelson (1877) noted that the species became very abundant in the Mt. Carmel area after 1 August, and most of the fall migration occurs in August. The fall counts of green herons do not show massive influxes of birds in late summer like those, for example, of the great egret (Fig. 12 and 29). The peak counts of green herons have come in late August, or early September, but the numbers have fallen off rather sharply about 8–12 September in all regions (Fig. 12). Relatively few birds linger into October, rarely as late as the 16th.

We have heard green herons flying at night, presumably in migration, from 2 September to 15 October between 8:00 p.m. and 4:00 a.m. CST, but strangely, never in August. We have heard very few, and the seasonal lateness of the records may merely reflect an accident of the sampling. Also indicative of low flight densities is the fact that we have never retrieved a green heron from any of the television tower kills of migrants.

The ratio of our spring (April–May) to fall (August–October) counts were similar in northern (1.0 bird seen in spring to 2.2 in fall) and southern Illinois (1.0:2.0); the ratio in central Illinois was inexplicably and strongly reversed (5.4 in spring to 1.0 in fall). It should be remembered that the entire central Illinois count was very low in 1969, when these data were gathered.

Green herons are seen very rarely in late fall and even in winter. There are at least two November

TABLE 5.—Breeding populations of green herons in various Illinois habitats. The figures may represent birds that are only foraging (not nesting) in the habitat.

Habitat	Hectares	Birds per 40.5 ha	Years	Type of Census	Region or County	Reference
Urban residential	40	0	1958	Strip	South	Graber & Graber 1963
Urban residential	143	0.3	1976–1977	Strip	South	This paper
Swampy prairie	27	0–12 (Avg 5.1)	1941–1944	Map	Sangamon (C) [a]	Robertson 1941*a*, 1942*a*, 1944*a*
Marsh	35	2–3 (Avg 2.3)	1957–1958	Strip	North	Graber & Graber 1963
Oak-hickory woods	11	7	1936	Nest	Lake (N)	Beecher 1942
Upland second-growth oak-hickory	23	0–4 (Avg 3.6)	1941–1944	Map	Sangamon (C)	Robertson 1941*b*, 1942*b*, 1944*b*
Second-growth hardwoods	6	0–13 (Avg 6.7)	1937–1938	Map	Rock Island (N)	Fawks 1937, 1938
Grazed bottomland woods	21	2	1955	Map	Macon (C)	Chaniot & Kirby 1955
Virgin floodplain forest	31	3	1948	Map	Sangamon (C)	Snyder et al. 1948
Mature bottomland forest	830	0–12 (Avg 0.8)	1973–1977	Strip	South	This paper
Mature upland oak-hickory	403	0	1974–1977	Strip	South	This paper
Pasture	179	1	1907, 1909	Strip	Central	Graber & Graber 1963
Pasture	70	0	1957, 1958	Strip	Central	Graber & Graber 1963
Pasture	357	0.2	1907, 1909	Strip	South	Graber & Graber 1963

[a] C refers to the central region of Illinois, and N to the northern, as shown on winter distribution maps, e.g., Fig. 7.

records for southern and central Illinois (George 1968, Bohlen unpublished notes). In addition to an early December record for East St. Louis (Comfort 1955*a*), green herons have been seen on Christmas counts at Decatur (Chaniot 1959), Forest Glen (Campbell 1972), and Wilmington (Bartel 1972). Bohlen (unpublished) noted that a green heron present 10 November in Sangamon County was at a warmwater ditch.

Food

N. D. Moore's description of the fishing style of the green heron was so apt that Ridgway (1895) quoted it, and it bears paraphrasing here. This heron fishes from the shore or a log or rock, preferring not to stand in the water, as the larger herons do, but if it sees some tempting morsel it will wade toward it. It steals upon its prey slyly, catlike, crouching and remaining motionless for a long time, sometimes advancing so slowly that its motion is barely perceptible. It jealously guards its feeding grounds. Haertel (1963) noted that green herons frequented the same areas as grackles.

Small samples of regurgitated food specimens from young green herons in northern Illinois consisted of small (2–10 cm) sunfish and minnows, with crayfish making up a large part of the food (Chase 1899, Olmstead 1906). The only observation on the food of an adult was very different. The stomach of a male collected by Gault (unpublished notes 1912) in August was filled with grasshoppers.

Specimen Data

Oberholser (1912) found the green herons of northeastern United States, including Illinois, to be very homogenous, representing the subspecies *virescens*.

LITTLE BLUE HERON *(Florida caerulea)*

(Fig. 14 and 15)

Spring Migration

Little blue herons apparently migrate northward beyond their breeding areas in spring and are not infrequently seen in central and northern Illinois at that time. The earliest sighting of the little blue for northern Illinois is 31 March (Brownell 1916). In central Illinois none have been reported before 3 April (1977) (R. J. Schifo unpublished). They arrive in southern Illinois in late March, the earliest recorded arrival for that area being 27 March (Kleen 1976*b*). Peak numbers occur in the south in late April and in the central part of Illinois in mid-May (Fig. 16). The distribution of spring records is shown in Fig. 17. In addition to those indicated, spring records exist for Ogle County, Morgan County, and southwest Pike County (no specific localities given).

Distribution

The little blue heron is a species of the southeastern U.S.A. and Central and South America (Fig. 15). In Illinois little blues have nested at least as far north as Pike County on the Missouri side of the Mississippi River (William H. Elder unpublished). The known breeding colonies have been mainly on the west side of the state along, or not far from, the Mississippi River (Fig. 17) though Butler (1897) indicated that they bred near the Illinois boundary in the lower Wabash valley of Knox and Gibson counties, Indiana. There are few recent observations of the species on the eastern side of the state even in the south. The only extant colony presently known

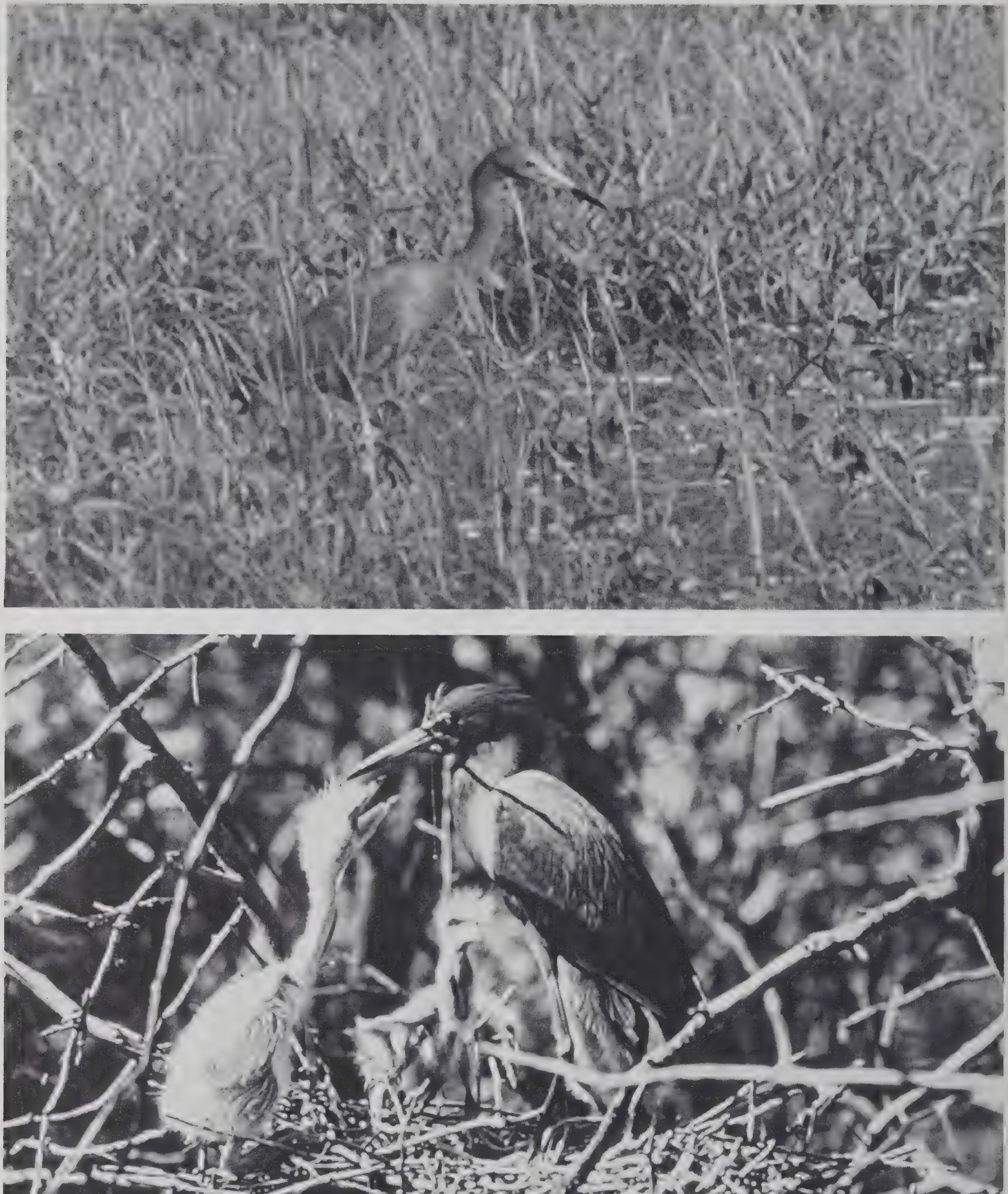

Fig. 14.—(Top) Adult little blue heron foraging at Union County Refuge, 13 June 1965. Larger (about 50 cm tall) than the green heron, the little blue has a dark bluish body, with purplish neck. (Bottom) Adult little blue heron in worn plumage, attending its nestlings at the Comment Sanctuary near East St. Louis. Photograph by Robert Starr.

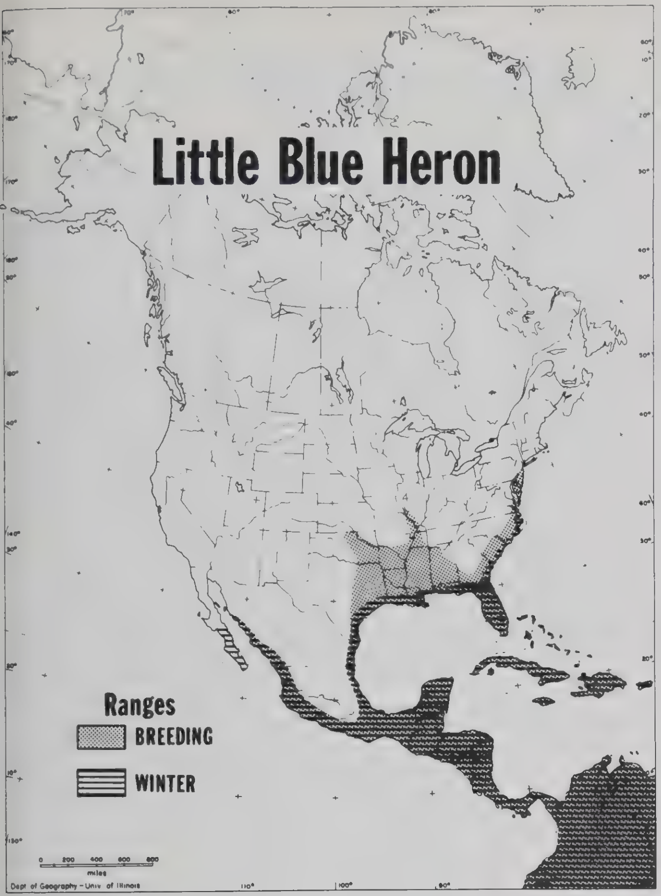

Fig. 15.—General distribution of the little blue heron.

in Illinois is the Comment Sanctuary, East St. Louis, but June records on the Mississippi as far north as Calhoun County (Anderson 1963*b*) and for Mason County on the Illinois River (Kleen 1974–1975) suggest the possibility of nesting in these areas. There are also June records of little blues (age unspecified) for northeastern Illinois (Ford 1956, Fawks 1970*b*, Dillon 1971). There are reports of little blues having nested in or near Illinois in the following areas: Dardenne Lakes near Peruque, Missouri (Jones 1936*a*, 1937*a*, and 1939*b*); Marais Temps Clair marsh, St. Charles County, Missouri (Jones 1937*a*); "Fults Island" (Fleig 1971); and Clear Creek near Gale, Illinois (Schwegman unpublished 1968, George 1968). There is reference to the nesting of little blues at Kidd Lake (Prairie du Rocher area) and near Chester (Kaskaskia Island?) though it is not clear whether nests were actually found (Fawks & Lobik 1975). A large colony that we found in 1975 on Billings Island on the Missouri side of the Mississippi was abandoned in 1976.

Nesting Habitats and Populations

The little blue heron has most often been found nesting in colonies with black-crowned night herons, but it also nests with great egrets, cattle egrets, snowy egrets, green herons, and great blue herons. The nesting colonies of little blues have generally been in thick stands of relatively young trees. At Billings Island the nests were in young black willows (about 13–15 cm DBH); the colony at Dardenne Lake was also in willows, but the Gale colony was in small cottonwoods. At Comment Sanctuary the nests were situated in a variety of deciduous trees (see under cattle egret). A very large colony near Bertrand, Missouri, was in shortleaf pine plantations on the floodplain of the Mississippi River (Greenberg & Heye 1971). The only obvious quality that these nesting sites have in common is their dense, thickety growth form, and we suspect that the foraging habitat may be more important to the colony than the woody vegetation available as nesting substrate. At Billings Island little blue heron nests were placed relatively low—2–5 m from the ground—in the crotches of black willows (Fig. 18). The nests would seem to be very vulnerable to raccoons and other predators, which may have a bearing on the island setting of several of the colonies, the Bertrand colony being a very important exception.

There are no population measurements for the little blue heron in Illinois. No little blues came within the transects of the cross-country censuses either in 1907–1909 or 1957–1958, indicating that the population was not large in either period. Individual colonies in the region have ranged in size from 25 or fewer birds at East St. Louis (Anderson 1964*a*) to an estimated 600 nests on Billings Island. The Billings colony is believed to have lasted only 3 years, changing from a few nests in 1973 to 600 in 1975 to none in 1976, the changes possibly related to population shifts in the large Bertrand colony (Paul Heye personal communication). The East St. Louis population was first reported nesting in 1962 at Grand Marais (Frank Holten) State Park (Anderson 1962*b*, Galbreath 1962). It returned there in 1963 and 1964 (Anderson 1964*a*), when the trees in the colony site were cut down and the birds moved to the nearby Comment Sanctuary. At the Comment Sanctuary the Southwestern Chapter of the Illinois Audubon Society has made counts of all herons in July every year, beginning in 1968. The number of little blues has varied from 10 adults and no young (1968) to 150 adults and 300 young in 1970 (Wrischnik 1973 and 1975–1976, Kleen 1974–1975 and 1976–1977), but these figures may include transient birds that do not nest locally.

Nesting Cycle

No studies have been made of the nesting cycle of the little blue heron in Illinois. Studies made in Arkansas and Florida (Palmer 1962) indicate the total time required to rear four young from the start of nest building to the independence of the young to be around 80 days. Nest building required 5–7 days. The laying of a clutch (usually 3–6 eggs) may take 6–12 days, as the eggs are laid about every other day. The incubation period is 23 days. The

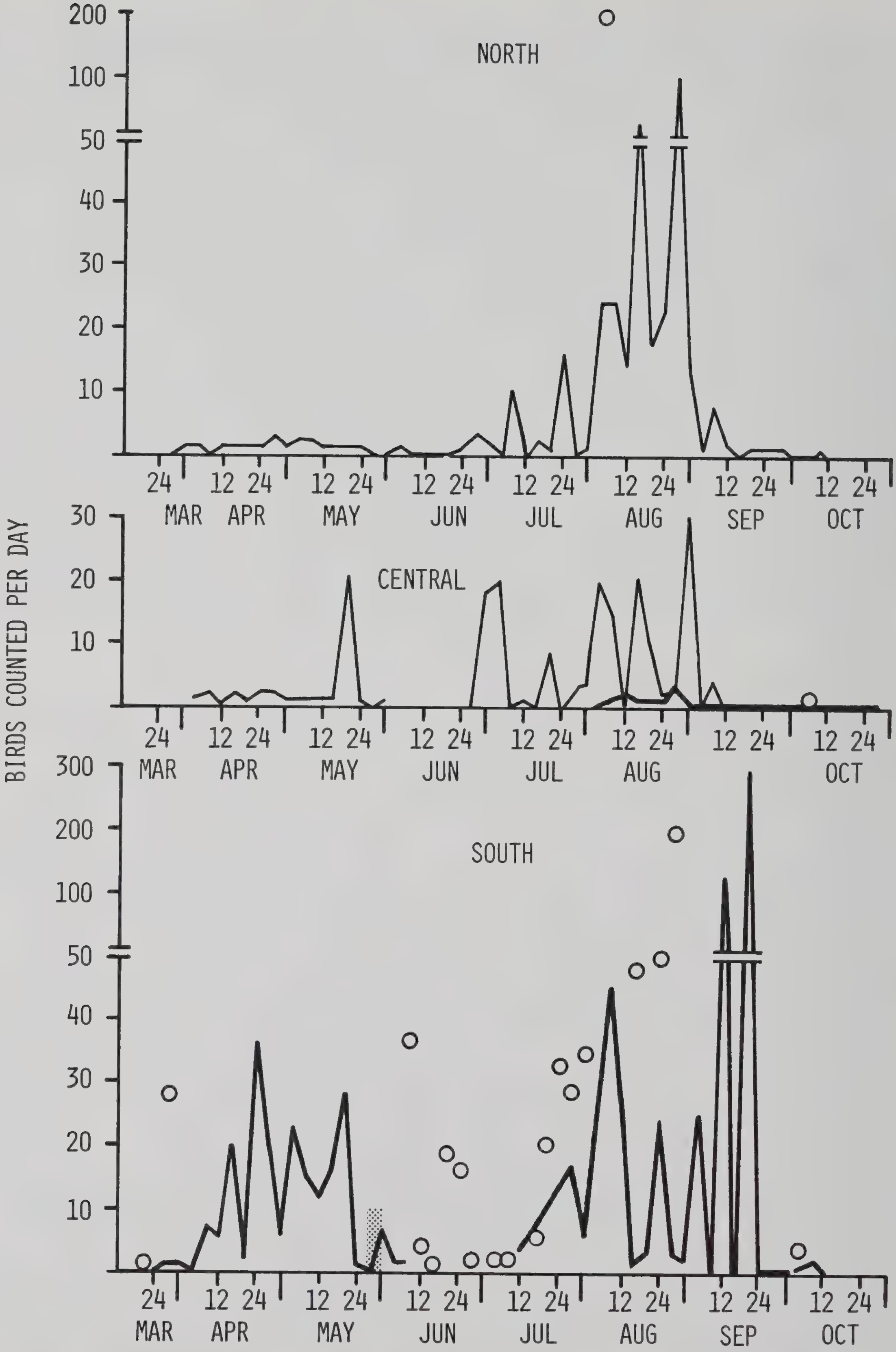

Fig. 16.—Migration seasons of the little blue heron in different regions of Illinois, as indicated by the highest counts of all observers (thin line) in north and central Illinois and our counts (heavy line) in central Illinois (1969) and southern Illinois (1967 and 1970). Circles represet counts made in other years or by other observers. The shaded area in the south represents the only recorded egg dates.

Little Blue Heron

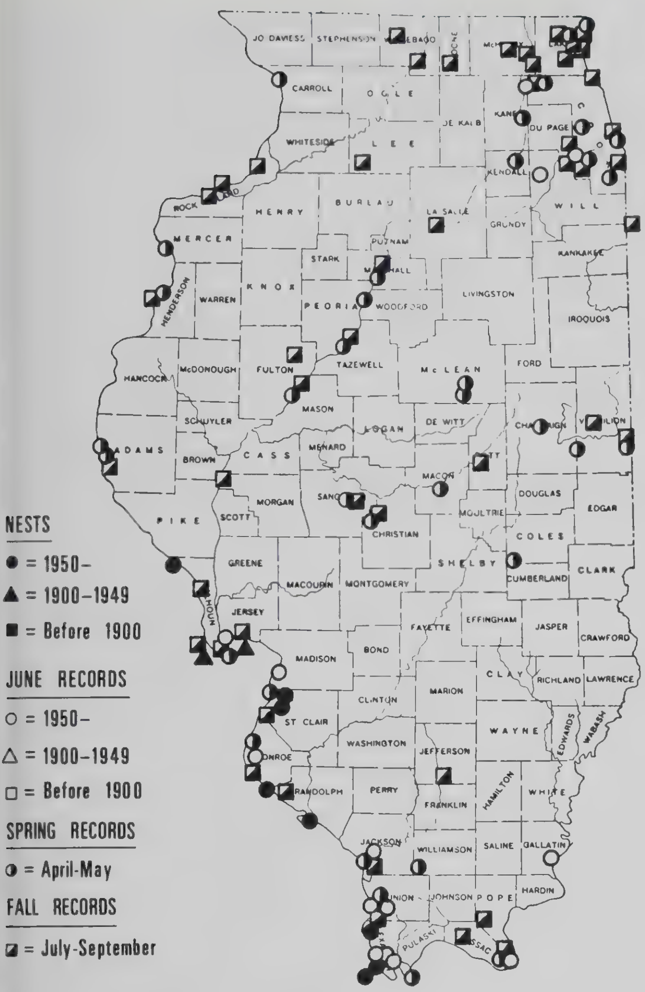

Fig. 17.—Distribution records of little blue herons in Illinois.

eggs hatch over a period of 3–5 days, since incubation starts with the laying of the second egg. At 30 days the young can fly a little but are still pursuing the adults for food. Some yearling birds nest, but what part of the population they constitute is unknown (Palmer 1962).

The little blues that we observed on Billings Island on 7 July 1975 had young around 17–20 days of age (Fig. 18), indicating that the eggs had hatched around 17–19 June from eggs laid 25–27 May. Peterson (1965) said that hatching at the Bertrand heronry, where 80 percent of the birds are little blues, occurred about the third week of May and that activity at the heronry subsided by the end of July.

There are no data on nest success or productivity of little blue herons in Illinois. The July censuses of the Comment heronry indicate an overall ratio of 1 adult to 1.8 young (Table 6), but it is not certain that these counts refer only to local birds. Counts are needed from the beginning of the nesting season to determine the actual number of pairs nesting, the number of eggs laid, and finally the number of young produced in each nest, or at least in a sample of nests.

There are no data on longevity, mortality, or productivity for the little blue heron. Greenberg & Heye (1971) found low levels of chlorinated hydrocarbons in eggs and tissues of young and adult little blues from the Bertrand colony. Colony sites of little blues have been lost from flooding at Clarksville (William Elder personal communication) and the cutting of trees at Gale (Schwegman unpublished) and Grand Marais (Wrischnik 1973).

Fall Migration

By the end of July or earlier young little blue herons are appearing north of the breeding colonies in Illinois (Smith 1941, Petersen & Ward 1966, Kleen 1974*d*). The peak of the northward movement appears to be in late August (Fig. 16.) Banding records suggest that some of the birds in southern Illinois in late summer have come from heronries in northern Mississippi (Dusi 1967). By the third week in September peak numbers occur in southern Illinois as these herons retreat from the north, and by late September most are gone from Illinois (Fig. 16). Very few linger into October. There is one record for northern Illinois on 9 October 1938 (Boulton & Pitelka 1938). In central Illinois little blues have been reported as late as 6 October 1975 (Kleen unpublished). The latest records for southern Illinois are 11 October (George 1968) and 10 October 1970 at Ware (Paul Heye unpublished) and two immatures seen on 10 October 1970 between the Union County Refuge and Grand Tower by R. R. Graber.

There appears to be a periodicity in the numbers of little blue herons seen in late summer in Illinois with peaks occurring about every 20 years (Fig 19). Table 6 shows that far greater numbers of immature birds (in white plumage) than adult birds (blue plumage) are seen in the fall, especially in the north and central parts of Illinois. Even in the south the ratio of one adult to five immature little blue herons is greater than would be accounted for by breeding production and probably indicates an influx of young birds from colonies outside of Illinois. It may also indicate a greater inclination on the part of young birds to wander northward and to linger in northern localities than is the case with adults. The distribution of fall records in Illinois is shown in Fig. 17.

Roosting

There are two accounts in the literature of roosts of the little blue heron in or near Illinois. Nelson (1877) said that toward evening little blue herons, along with other herons, moved to a common roosting place in a large opening in the Mississippi bottoms (locally called the "deadening") about 6 miles from Cairo. A few straggled in about an hour before sunset, the numbers reaching a peak just before sunset. At the Dardenne marsh (St. Charles County, Missouri) Short (1938) wrote that on 26 August of that year 200 little blues were flying in small bands of

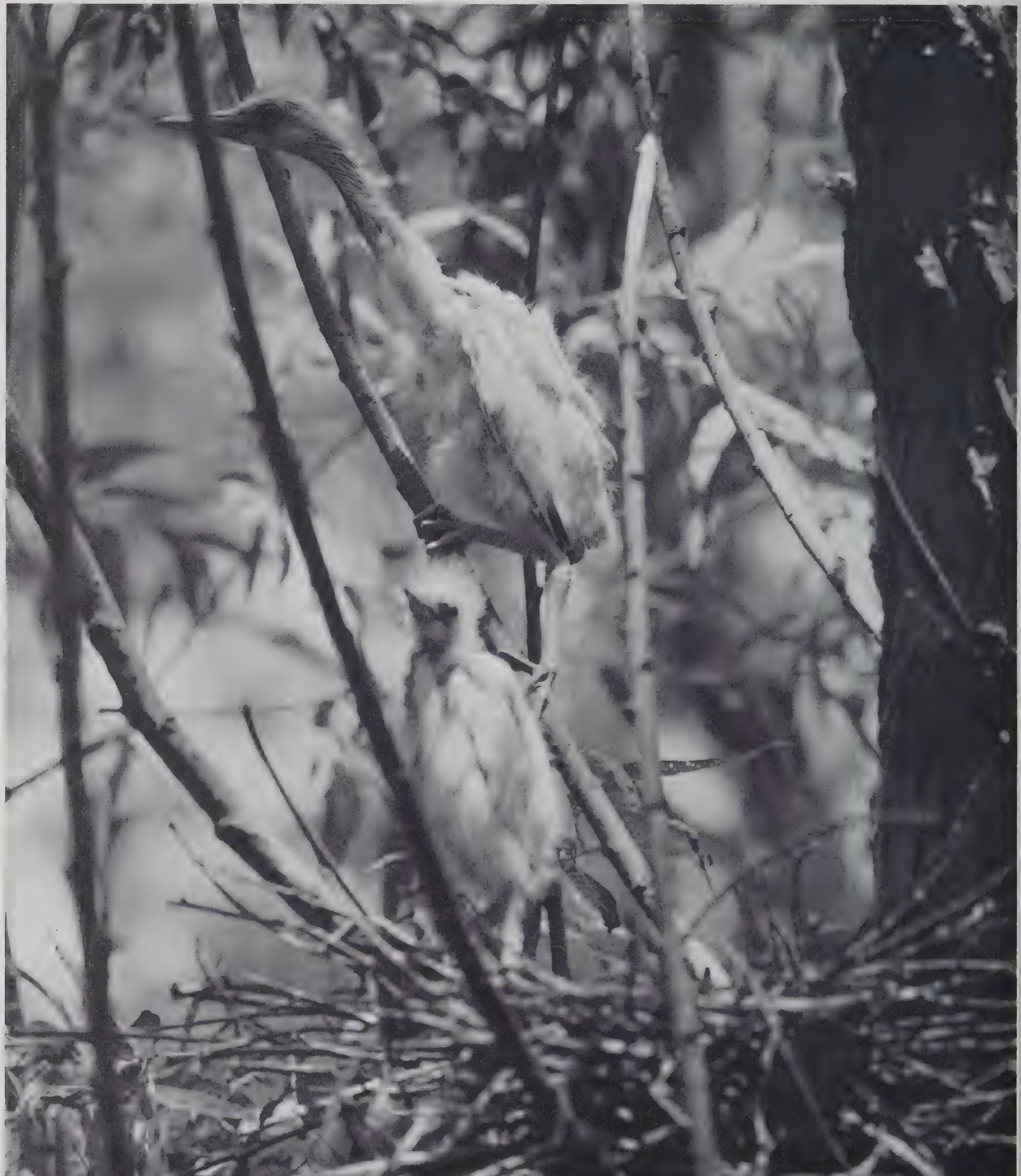

Fig. 18.—Young little blue herons near their nest on Billings Island, 7 July 1975. Note black tips of the primaries, a character lacking in the similar-appearing cattle egret young (Fig. 25). Little blues are white for more than a year before attaining the all-blue adult plumage.

Table 6.—Age ratios of little blue herons in Illinois.

Region of State	Time of Year	Number of Birds in Sample	Percent in Plumage Color			Ratio of Blue:White
			Blue	Calico	White	
North & Central	April to June	48	50	37.5	12.5	4:1
South	April to June	182	73	0	27	2.7:1
South	June	43	70	11	29	2.7:1
South[a]	July	1,526	36	0	64	1:1.8
North & Central	July to Oct.	283	3	0	97	1:30
South	July to Oct.	671	16	4	80	1:5

[a] Annual census made in July (1968–1976) at Comment heronry. Other data in the table are counts made of foraging birds. Counts for the southern region were made by us; those for the north & central regions come from the literature from 1926 to 1976.

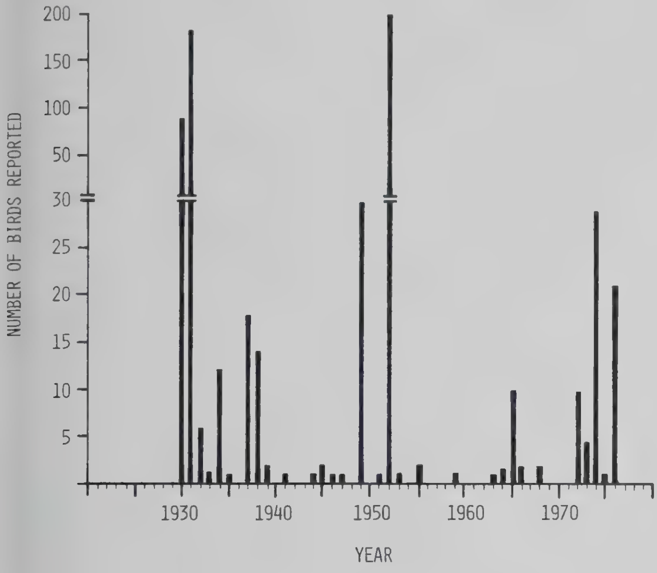

Fig. 19.—Numbers of little blue herons reported in Illinois in late summer in different years.

15–50 with great egrets to roost in a buttonbush marsh.

Food

Food items in regurgitated boluses picked up at the colony on Billings Island in 1975 are listed in Table 7. It is readily apparent that the bulk of the food in this sample is rather small fishes. Most of the fishes were about 5 cm in length, the largest 9.5 cm and the smallest (mosquitofish), 1.5 cm. Frogs and crayfish are the only other important items in the sample. The items in Table 7 represent a very small and hastily gathered sample from a small area in the colony. Plans for a more representative collection were thwarted by the abandonment of the heronry in 1976. The diet listed in Table 7 is not grossly different from that listed by Hanebrink & Denton (1969) for little blue herons in a colony at Luxora, Arkansas, but is

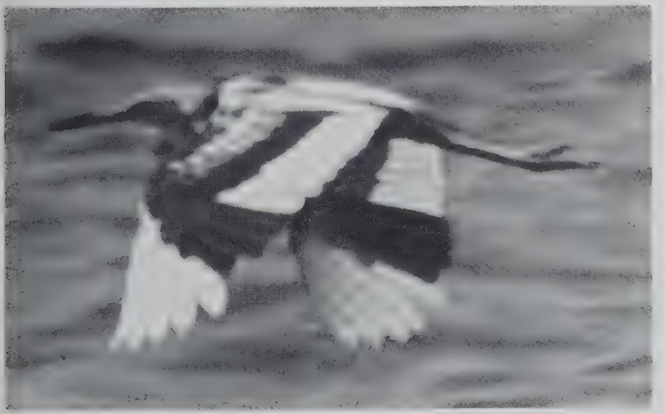

Fig. 20.—Subadult little blue heron in mixed white and blue (calico) plumage (see Table 6). Photograph by Glen C. Sanderson.

Table 7.—Food[a] of nestling little blue herons on the Mississippi River near Commerce, Missouri.

Food Item	Number	Wet Weight (Grams)	Percent of Weight
Invertebrates			
Crayfish—Cambaridae	18	32.3	9.4
Orconectes sp.	3		
Orconectes immunis	13		
Procambarus acutus	1		
Cambarellus sp.	1		
Insects	20		
Dragonflies—Odonata	1 larva & 7 adults	0.2	
Bug—Hemiptera	1		
Belostomatidae *(Lethocerus)*	1		
Notonectidae *(Buenoa)*	1		
Beetles—Hydrophilidae	9 larvae		
Vertebrates			
Fish—Pisces	221	240.2	69.7
Gizzard shad *(Dorosoma cepedianum)*	69	65.0	18.9
Grass pickerel *(Esox americanus)*	1	2.9	0.8
Carp *(Cyprinus carpio)*	81	48.0	13.9
Golden shiner *(Notemigonus crysoleucas)*	16	21.0	6.1
Bigmouth buffalo *(Ictiobus cyprinellus)*	13	17.5	5.1
Mosquitofish *(Gambusia affinis)*	8	1.3	0.4
White bass *(Morone chrysops)*	2	13.4	3.9
Flier *(Centrarchus macropterus)*	3	1.1	0.3
Sunfish *(Lepomis* sp.)	3	1.9	0.5
Warmouth *(L. gulosus)*	16	42.9	12.4
Green sunfish *(L. cyanellus)*	5	18.4	5.3
Orangespotted sunfish *(L. humilis)*	2	5.7	1.6
Bluegill *(L. macrochirus)*	1	0.9	0.3
White crappie *(Pomoxis annularis)*	1	0.2	0.1
Frogs—Salientia			
Leopard frog *(Rana utricularia)*	16	72.0	20.9

[a] Regurgitated boluses were collected under nests 30 June and 7 July 1975.

less varied. Little blues feed entirely in shallow waters, and lagoons, marshes, and swampy areas are vital to their survival.

Plumages

The little blue heron is distinguishable in juvenile, first year, and adult plumages. The dark slate tips of the primaries (Fig. 18) readily separate the juvenile little blue heron from the all-white juvenile cattle egret (Fig 25) and the snowy egret. In the spring of the year following hatching, the white plumage is replaced in patches over the body, producing a "calico" bird (Dusi 1967, Fig. 20). By the second breeding season, the slatey blue plumage with purplish mantle is assumed.

CATTLE EGRET *(Bubulcus ibis)*

(Fig. 21 and 22)

Spring Migration

In Illinois a few cattle egrets may arrive as early as March, but most appear in mid- or late April (Fig. 23). The earliest arrival date for this species in northern Illinois is 4 April at Joliet (Fawks 1967*a*). The earliest arrival in central Illinois is 9 March at Banner, Fulton County (Princen 1975), whereas in southern Illinois the earliest the cattle egret has been reported is 27 March at East St. Louis (Kleen 1976*b*). One would expect earlier arrival in southern Illinois than farther northward, and peak numbers of cattle egrets appear slightly earlier in the south (the third week of April) than in other portions of the state (Fig. 23).

Cattle egrets are noted for overmigrating and appearing far northward of their known breeding grounds. Palmer (1962) says that the migration is probably diurnal. No observations of the migration of cattle egrets in Illinois have been reported.

Distribution

Before 1930 cattle egrets were found chiefly in southern Spain, Portugal, and Africa. In the 1930's they established themselves in northern South America and spread from there to Florida in the 1940's. The first reported nesting for North America was in Florida in 1953 (Crosby 1972). The rapid establishment of breeding colonies of the cattle egret up the eastern coast and along the Gulf Coast and thence along waterways to the interior is shown in Fig. 21.

The cattle egret was first reported in Illinois by C. Clark and R. Pringle on 10 August 1952 at Saganashke Slough in southeastern Cook county (Nolan 1952). There were few reports of this bird in the state until 1962, when the first evidence of nesting in Illinois was observed (Anderson 1962*b*, Comfort 1962). Since then, the number of observations of the cattle egret in Illinois has increased yearly, and the bird has now been reported in at least 55 counties (Fig. 24), including Kane County for which no specific locality was given (Kleen & Bush 1971*b*). However, nesting has been observed only in St. Clair (Wrischnik 1973), Monroe (Comfort 1962, Fleig 1971), and Will (Kleen & Bush 1971*c*) counties (Fig. 24). In 1975 a large number (300 pairs) nested on Billings Island (Scott County, Missouri) in the Mississippi River less than 1 km from the Illinois state line (about 2 km west of Willard, Alexander County).

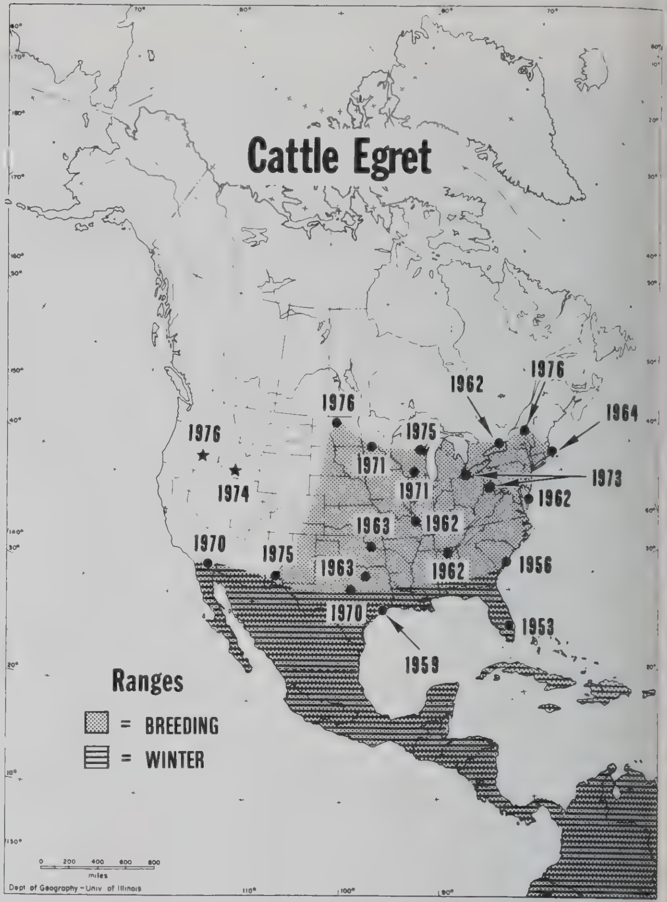

Fig. 21.—General distribution of the cattle egret. The species also has a broad distribution in the Old World. Dates (dots) indicate extension of nesting range in the USA since 1953.

Nesting Habitats and Populations

The known number of breeding cattle egrets in the state at present is less than 100 birds annually, but some rookeries of the species probably have not been found. Colonies may exist near Belleville, in Oakwood Bottoms in Jackson County or on the Mississippi River nearby, around Horseshoe Lake in Alexander County, along the Illinois River from Meredosia to Lacon, and in extreme southeastern Lake County, since cattle egrets have been seen in these areas during the breeding season.

Palmer (1962) says that the cattle egret tends to

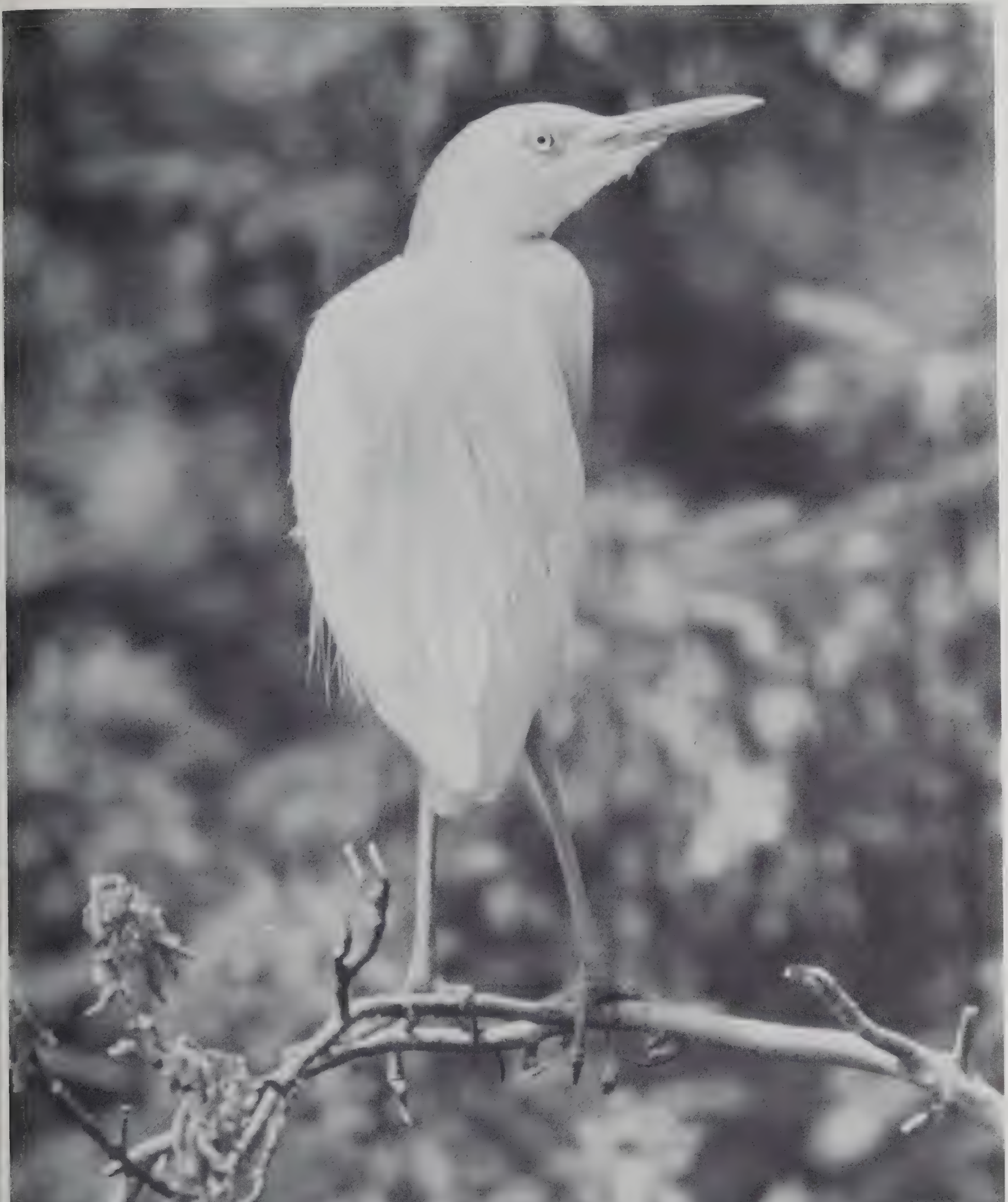

Fig. 22.—Adult cattle egret, a small (about 40 cm tall), white heron, which has become established in Illinois only in recent years. Note aigrette plumes on the back. In breeding season, adults have patches of buff on the front and back.

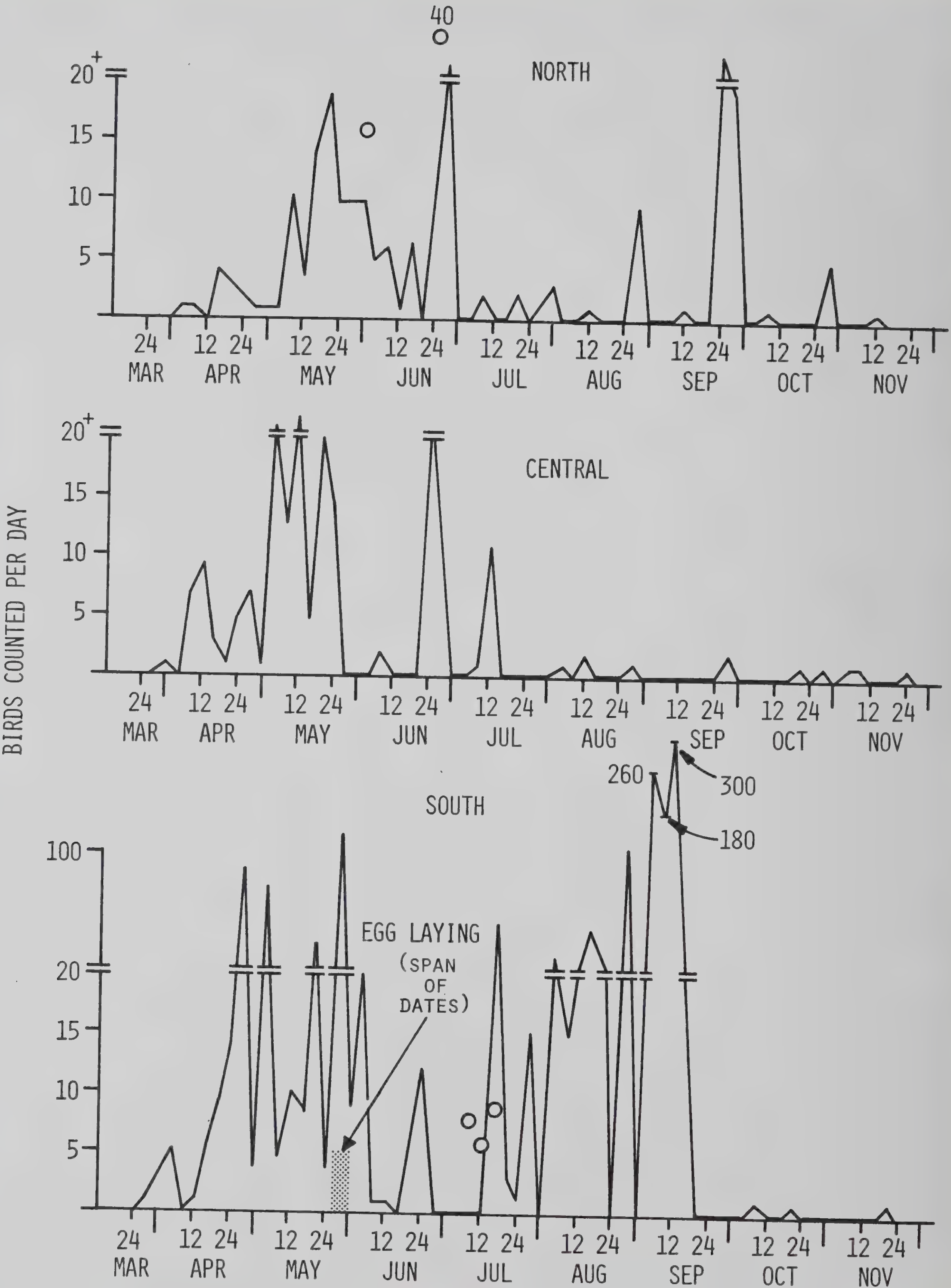

Fig. 23.—Migration seasons of the cattle egret in different regions of Illinois, as indicated by the highest recorded counts of all observers. Circles represent counts made at nesting colonies.

Cattle Egret

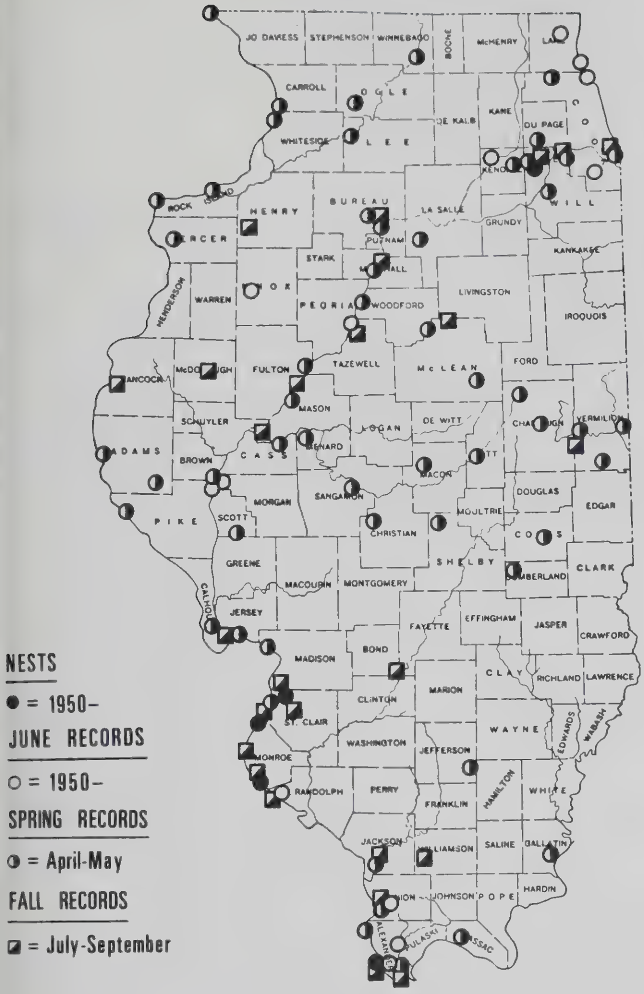

Fig. 24.—Distribution records of the cattle egret in Illinois.

nest with other herons when colonizing new areas. In every case thus far in Illinois, it has been found nesting with other heron species. At Lake Renwick (Will County) cattle egrets have nested with great egrets, black-crowned night herons, and green herons. At the Comment Sanctuary (St. Clair County), they have nested with great egrets, black-crowned night herons, little blue herons, and snowy egrets. On Billings Island cattle egrets were nesting with little blue herons and black-crowned night herons.

Nests of cattle egrets were placed 3–6 m up in small to medium-sized box elders on a small island in Lake Renwick. At Billings Island the nests were situated in crotches 1–5 m up in young black willows, which grew in a thick stand on this sandbar island. At the Comment heronry, nests were placed in small (10–36 cm DBH) ashes, elms, hawthorns, persimmons, and pin oaks. At the time we visited this heronry, the herons were gone; so it was impossible to tell which nests had been occupied by which species. This heronry lies in a small low-lying woodlot surrounded by roadways leading to nearby St. Louis. At Lake Renwick and at Billings Island the cattle egrets were generally found nesting on the periphery of the rookeries.

Nesting Cycle

No observations on the nesting cycle of the cattle egret in Illinois have been published. The following description of the events in the cycle and their timing are from studies made in Florida (Palmer 1962). Pair formation takes 2–3 days and nest building 4–7 days though material may be added to the nest throughout incubation and even after the eggs have hatched. A clutch of four or five eggs is laid. Incubation lasts 23 days and starts with the first egg so that the eggs hatch over a period of days. Both sexes incubate. The young are fed by both parents and spend about 30 days in the nest. At 40 days, young cattle egrets can fly short distances, and by 50 days can fly fairly well. Thus, the nesting cycle from the beginning of nest building to the independence of the young requires about 90 days.

The only clues we have as to the seasonal timing of the nesting cycle of the cattle egret in Illinois are from observations and photographs made at the heronry on Billings Island. On 7 July 1975 the young at this colony appeared to be between 15 and 18 days of age, judging from their behavior, size, and feathering (Fig 25). These birds must have hatched between 19 June and 22 June from eggs laid 27 May–30 May, the start of the nesting cycle (courtship) beginning in mid-May or earlier. Sometimes nest building is delayed by inclement weather (Palmer 1962). The cattle egrets appear to be later in nesting than are black-crowned night herons in the same heronries. At Lake Renwick on 26 June 1972, we found that black-crowned night herons had young 25–30 days old, whereas the cattle egrets appeared to be incubating. On 7 July 1975 at Billings Island, all of the black-crowned night herons had fledged young, while the cattle egrets still had young in the nests. The later nesting of the cattle egret has been noted in the literature (Kibbe 1976), and this characteristic may be helpful in enabling the species to colonize in more northern localities as well as to avoid nesting losses from early spring storms.

There are few data on productivity or nesting success in Illinois. Five young were produced in two nests at Lake Renwick in 1971 (Kleen & Bush 1971*c*). There were 22 young counted in a sample of 12 nests at Billings Island on 7 July, but at this date some of the older young might already have left the nests. Numbers of cattle egrets counted in the annual censuses of the Comment heronry near Caseyville, Illinois, vary from 2 to 9 adults and 0–20 young (Wrischnik

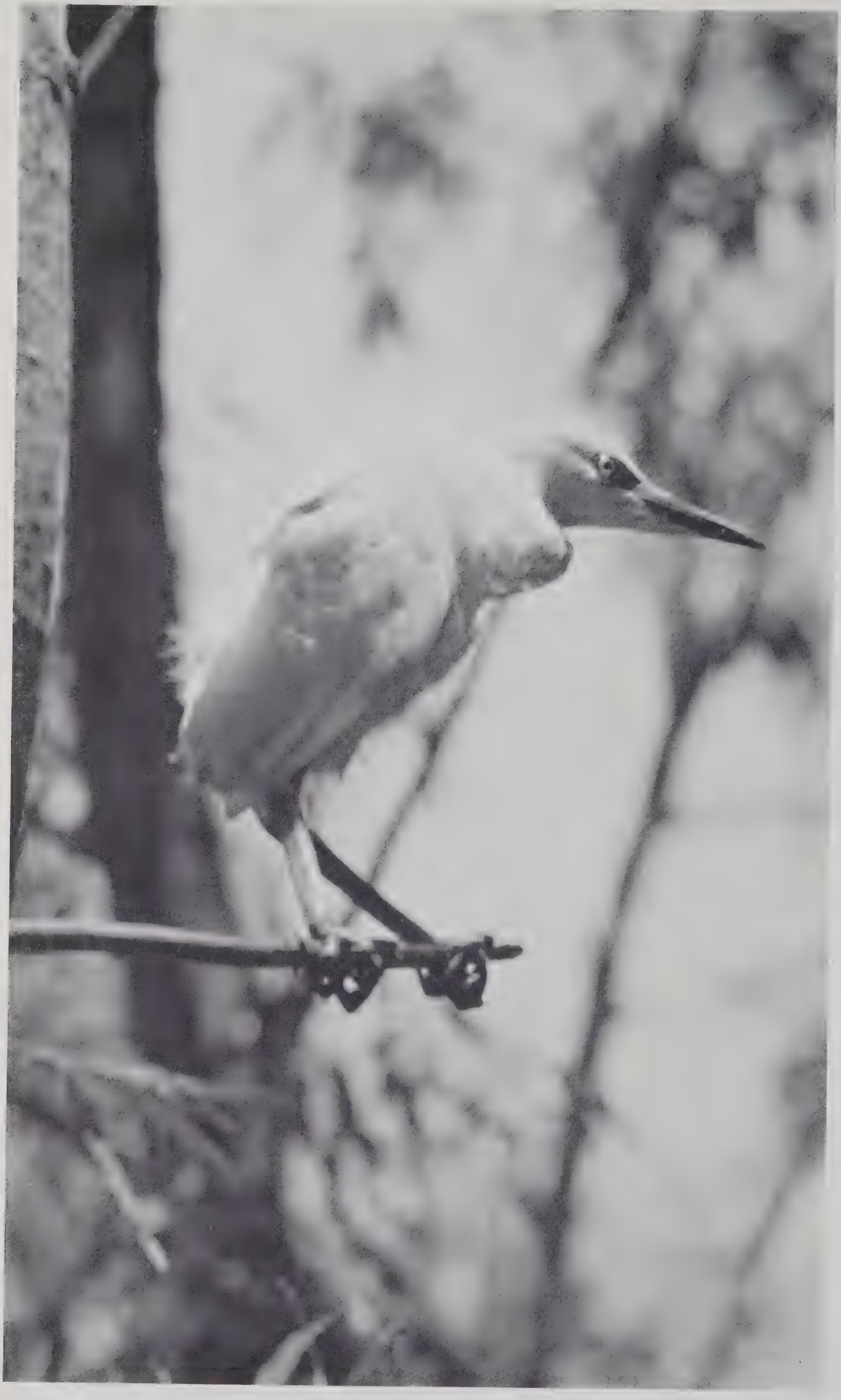

Fig. 25.—Young cattle egret just out of its nest. Note white tips of the primaries, a character distinguishing young cattle egrets from young little blue herons (Fig. 18).

1973 and 1975–1976, Kleen 1974–1975 and 1976–1977). Productivity can not be calculated from these data, as they do not account for adults away from the colony at the time the census was made, for adults that may have left after an unsuccessful attempt at nesting, or for postbreeding birds coming into the colony from farther south.

Fall Migration

From these observations, it appears that the cattle egret nesting cycle in southern Illinois is probably finished by late July and the young are able to leave the heronries by mid-August. Anderson (1962*c*) wrote that cattle egrets had left the St. Louis area by the last of August in 1962. The departure of breeding birds and their young may be obscured by late summer influxes of cattle egrets from other areas, swelling the population to peak numbers in early September along the Mississippi River from St. Louis southward, e.g., 300 seen 12 September 1970 (Anderson 1971*b*, Petersen 1971) and 260 counted on 3 September 1973 (Kleen 1974*a*).

Cattle egrets have remained around the northern Illinois rookery at Plainfield until the last week in September in 1970, 1973, and 1974 (Fawks 1971*a* and 1974, Kleen & Bush 1973). Most cattle egrets leave Illinois by late September (Fig. 23), but a few may linger on. Late records for the north include five seen on 25 October 1974 near Opheim, Henry County (M. K. Mahoney unpublished) and one reported as far north as Indiana Dunes on 11 November 1971 (Petersen 1971). There are several November records for central Illinois: Vermilion County (near Homer)—3 November 1975 (Kleen 1976*a*); Mason County—8 November 1975 (Kleen 1976*a*); near Lacon—10 November 1968 (Princen 1969); and Hamilton—23 November 1974 (H. D. Bohlen unpublished). The latest record for the species in Illinois is one seen at Lake Carlyle, Bond County, on 7 December 1975 (Kleen 1976*a*). The number of reports of cattle egrets remaining late in Illinois in 1975 may have been due in part to the fact that the temperature throughout November of that year was

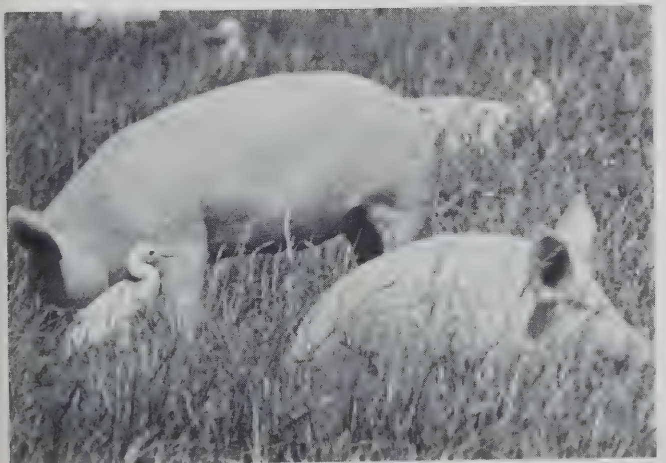

Fig. 26.—Cattle egrets foraging among pigs in Gallatin County, 10 May 1972.

Table 8.—Regurgitated food items collected from cattle egrets at Billings Island heronry on 3 June and 7 July 1976.

Food Item	Number	Wet Weight (Grams)[a]	Percent of Weight
Invertebrates			
Molluscs			
Slug—Limacidae			
(Deroceras reticulatum)	1		
Insects			
Orthoptera			
Pigmy locusts *(Tettigidea lateralis)*	53	3.7	0.7
Short-horned grasshoppers *(Melanopus)*	221	47.0	8.9
Slant-faced grasshoppers—Acridinae	249	28.0	5.3
Band-winged grasshoppers—Oedipodinae	24	3.3	0.6
Dissosteira carolina	2	0.9	
Katydids—Phaneropterinae	7	2.8	0.5
Amblycorpha oblongifolia	5	2.5	0.5
Cone-headed grasshoppers *(Neoconocephalus)*	15	2.3	0.4
Meadow grasshoppers *(Conocephalus fasciatus)*	351	44.7	8.5
Tree crickets *(Oecanthus nigricornus)*	4	0.3	
Ground crickets *(Nemobius)*	675	43.8	8.3
(Nemobius fasciatus)	7	0.9	
Field crickets *(Gryllus)*	12	7.6	1.4
Cockroach—Blattidae *(Ischnoptera deropiltiformis)*	1	0.1	
Hemiptera			
Negro bugs—Corimelaenidae *(Allocoris pulicaria)*[b]	13		
Stink bugs—Pentatomidae	4	0.3	
Homoptera			
Leafhopper—Cicadellidae	1		
Cicadas *(Tibescen)*	3	5.0	0.9
Coleoptera			
Ground beetles—Carabidae	48	4.0	0.8
Calosoma calidum	1		
Calosoma scrutator	1		
Rove beetle—Staphylinidae[b]	1		
Soldier beetles—Cantharidae *(Cauliognathus marginatus)*	7	0.8	
Ladybird beetles—Coccinellidae *(Coleomegilla maculata)*	8	0.4	
Scarab beetles—Scarabaeidae	27	20.0	3.8
Dung beetles *(Aphodius)*	4		
Leaf beetles—Chrysomelidae			
(Chrysomela scripta)	1		
(Myochrous denticollis)	2		
(Oedionychis vians)	1		
Snout beetles—Curculionidae			
(Baris)	1		
(Listronotus)	1		
Beetle larvae	10	0.6	

(Table 8 continued on next page.)

TABLE 8.—Continued

Food Item	Number	Wet Weight (Grams)[a]	Percent of Weight
Lepidoptera			
Measuring worm moths—Geometridae	2		
Butterfly larva—Pieridae *(Colias eurytheme* or *philodice)*	1		
Moth larvae—Noctuidae		2.8	0.5
Cutworms *(Agrotis ipsilon)*	20		
Clover-looping owlets *(Caenurgina crassiuscula* or *erechtea)*	2		
Leucania	1		
Green clover worms *(Plathypena scabra)*	15		
Armyworms *(Pseudaletia unipuncta)*	2		
Spodoptera ornithogalli	3		
Pyralidae	1		
Diptera			
Horseflies *(Tabanus)*	53	4.0	0.8
Tabanus atratus	15	9.1	1.7
Robber flies—Asilidae	3	0.4	
Houseflies—Muscidae	5	0.1	
Blowflies *(Phormia regina)*	158	4.0	0.8
Tachnid flies—Tachnidae	3	0.2	
Fly larvae	7	0.8	
Hymenoptera			
Wasp—Ichneumonidae (a lepidopteran larvae parasite)[b]	1		
Tiphiidae (a beetle larvae parasite)[b]	1		
Ant—Formicidae *(Camponotus)*[b]	1		
Wasps—Vespidae	2		
Bee—Halictidae *(Dialictus)*	1		
Insect larvae	4	0.2	
Arachnida		13.8	2.6
Wolf spiders—Lycosidae	8		
Arctosa rubicunda	1		
Lycosa avida	32		
Lycosa carolinensis	15		
Lycosa helluo	1		
Pardosa saxatilis	30		
Trochosa terricola	1		
Egg cases	4		
Vertebrates			
Amphibians			
Toad *(Bufo woodhouseii)*	39	162.9	30.9
Frog—Hylid	1		
Mammals			
Rodents			
Vole *(Microtus ochrogaster)*	3	90.0	17.1
House mouse *(Mus musculus)*	1	20.0	3.8
Total		*527.3*	*98.8*

[a] Wet weight of preserved specimens.

[b] Very small items came from toad stomachs, the toads having been eaten by egrets, and from being on host species eaten by egrets.

3°–5° C above average (U.S. Department of Commerce, Environmental Data Service 1975–1976).

Food

The cattle egret's habit of foraging among cattle, horses (Comfort 1962), hogs (Mumford 1961*b*, Fig. 26), and even white-tailed deer (M. Morrison unpublished) has given the species its common name. It has been assumed that the cattle egret eats ticks from its grazing associates, and in some localities it has been called the "tick bird." However, studies of the food habits of the cattle egret (Fogarty & Hetrick 1973, Jenni 1973) indicate that ticks constitute very little of its food. We found no ticks in the food samples we examined (Table 8). It appears that these small herons are interested in the insects stirred up by the cattle as they move around grazing, and the egrets have been observed to leave resting animals to follow those moving about (Hanebrink & Denton 1969). They may also get flies (especially Tabanidae) from livestock, as flies are a regular item in the cattle egret's diet.

The cattle egret is also often seen foraging on its own, away from livestock, in low meadows, pastures, roadside ditches, and on the grassy margins of shallow bodies of water. The major portion of its food appears to be insects, especially Orthoptera (grasshoppers, crickets, and katydids). Diptera (flies), ground beetles, insect larvae, slugs, and spiders are also eaten in considerable numbers. A number of toads and four mammals (voles and a house mouse) were found in regurgitated food boluses at the heronry on Billings Island (Table 8). Our list of food items for the cattle egret agrees fairly well with that given by Hanebrink & Denton (1969), who made a similar study at a heronry at Luxora, Arkansas.

The cattle egret's diet indicates that it competes very little with most other herons for food. When cattle egrets and little blue herons were observed feeding at the same lagoons, the cattle egrets were seen searching the low-lying vegetation on the shore, whereas the little blue herons were feeding in the water. The diet of the snowy egret, as indicated by studies made in other states, appears to be somewhat like that of the cattle egret and somewhat like that of the little blue heron. Since cattle egrets have been observed outside of Illinois competing with the snowy egret for nesting sites (McCaskie 1973), it may be that the cattle egret will provide serious competition for this species.

REDDISH EGRET

(Dichromanassa rufescens)

Reddish egrets infrequently reach southern Illinois in late summer. Nelson (1876) wrote that they were "common" (but wary and remained apart from other herons) in lagoons and marshes about Cairo, Illinois, in the latter half of August, 1875. This record, if accurate, is remarkable, as all other references to this species indicate that it is rare in Illinois. Nelson also mentioned unusually high water for the season.

J. E. Comfort reported seeing a reddish egret in Illinois at Chain-of-Lakes bridge (St. Louis) on 29

July 1949 (Comfort 1949, Mayfield 1950*a*). Another sight record for the species in this area was one seen by A. Bolinger (and later seen by J. E. Comfort) on 30 September 1951 in marshes in St. Charles County, Missouri (Comfort 1951).

GREAT EGRET *(Casmerodius albus)*

(Cover, Fig. 27 and 28)

Spring Migration

Great egrets do not generally begin to appear in Illinois until March even in the south (Fig. 29). Early arrival dates are 9 March in central Illinois (Nolan 1955*a*) and 17 March in the north (Brown 1963*a*), but the species is not usually detected in Illinois until after 20 March. The migration may last into May or even early June (Fig. 29). Actual migration flights have apparently never been observed.

Distribution

The great egret has a nearly worldwide range, and though primarily southern in distribution in the United States, it comes well north (e.g., Minnesota and Canada) along major rivers and both coasts (Fig. 28).

In Illinois, as elsewhere, the distribution has followed the enormous ups and downs of the general population (see under breeding population). The great egrets' occurrence in the Illinois area dates at least to about 1200 AD (Parmalee 1957), but there is no way to tell whether such a record refers to breeding birds, migrants, or both. The present breeding distribution, similar to that of the great blue heron, is mainly along the large rivers (Fig. 30). The great egret, compared with the great blue, has been an infrequent constituent of Indian middens, but six bone specimens of the egret were found at Cahokia (Parmalee 1957).

Nesting Habitats and Populations

The great egret nests almost invariably with other species of herons, particularly great blues, black-crowned night herons, or both. We know of no Illinois colony that consisted solely of great egrets. Egrets often place their nests in the trees that have great blue nests (see Table 2), but in the Pekin colony, where great blues used principally cottonwood trees, the egrets used more silver maples (Bjorklund 1975). Bjorklund (1975) and Hammerslough & Bjorklund (1968) also pointed out that great egret nests were generally placed lower (15–18 m high) than nests of great blues (18–24 m high) in the same colony. Egrets show much more flexibility than great blues in their choice of nest sites, as evidenced especially by birds in colonies at Plainfield and East St. Louis, Illinois, and Commerce, Missouri. At these places great blues were absent, and there was neither extensive forest nor large trees, but great egrets nested there among smaller herons at heights below 9 m. However, in Illinois many more great egrets nest with great blues than with the smaller herons only.

The foraging habitat of the great egret has not been precisely defined. In the nesting season we have seen them fishing most often in lagoons of the floodplains of the major rivers within 9.6 km of the colony. If there is a consistent difference in the foraging habitat of this species from that of the great blue, it has not been determined, and they often fish at the same lagoon. Strangely, there are no data on preferred water depths of either species. Stewart (1949) stated that they require clear water.

In considering any population of migratory birds, it is important to differentiate between the local breeding population and the migrant population that passes through an area or a population that uses the area for reasons other than nesting. A number of species of herons exhibit a special migration pattern, in which, after the nesting season, they first move north (sometimes hundreds of kilometers), where they spend the rest of the summer and fall, before migrating back south for the winter. There are, thus, two summer populations in Illinois—(1) the Illinois breeding population, which arrived in spring, and (2) a population that arrives in summer from the south, where nesting starts and finishes much earlier than in Illinois. Coffey's (1943) data on great egrets banded in spring as juveniles in Mississippi and recovered (five birds) in Illinois mainly in July and August clearly illustrate the pattern of northward movement.

Within historic times, great egret populations in Illinois have undergone at least one major decline and a major expansion, and the breeding population is now declining again. The species was abundant in Illinois well into the 19th century (Barnes 1926), nesting at least as far north as the Kankakee valley (Woodruff 1908, Butler 1934). The onset of the great egret's decline is not precisely dated, but by 1890 both the breeding and visitant populations were seriously depleted, and the decline was attributed to plume hunters (Barnes 1912 and 1926, Woodruff 1908). The breeding population was gone from the central Mississippi and Illinois valleys by about 1900 (Barnes 1912 and 1917, Widmann 1907). The U.S. population of great egrets probably reached its low point in the early 1900's (Bent 1926, DuMont 1935), and there were few records of the species in Illinois between 1900 and 1925. By 1916 the selling of egret plumes was illegal in Illinois (Lucey 1916), and strong opposition to the persecution of egrets and other birds was developing nationwide. It was an important landmark in the history of conservation, showing that the tides of destruction can be turned.

Great egrets began to return to Illinois rivers,

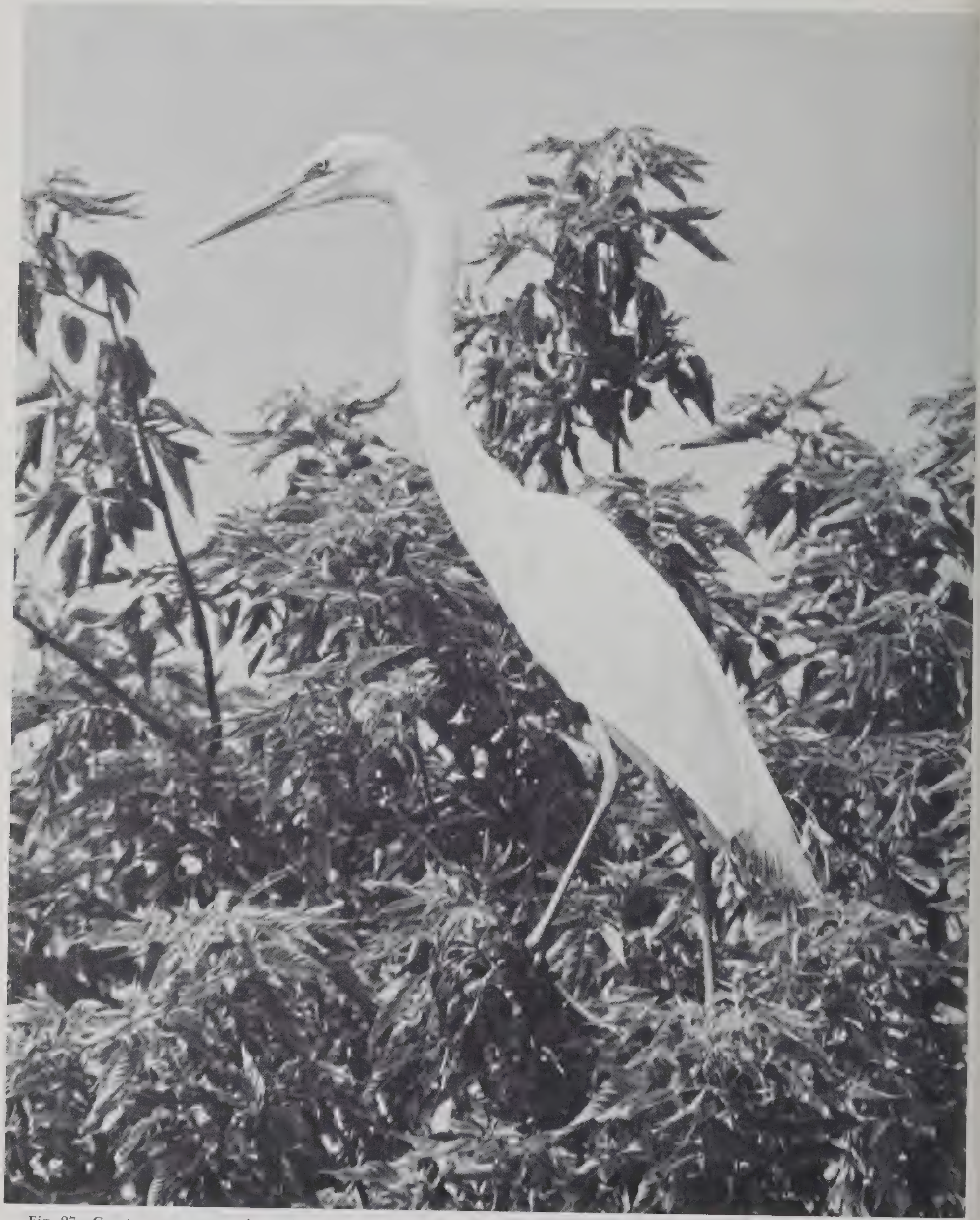

Fig. 27.—Great egret at a nesting colony near Plainfield. The largest (about 80 cm tall) white heron in Illinois, it has a yellow or orangy bill and black legs. Note aigrette plumes on the back, characteristic of the adult in breeding season.

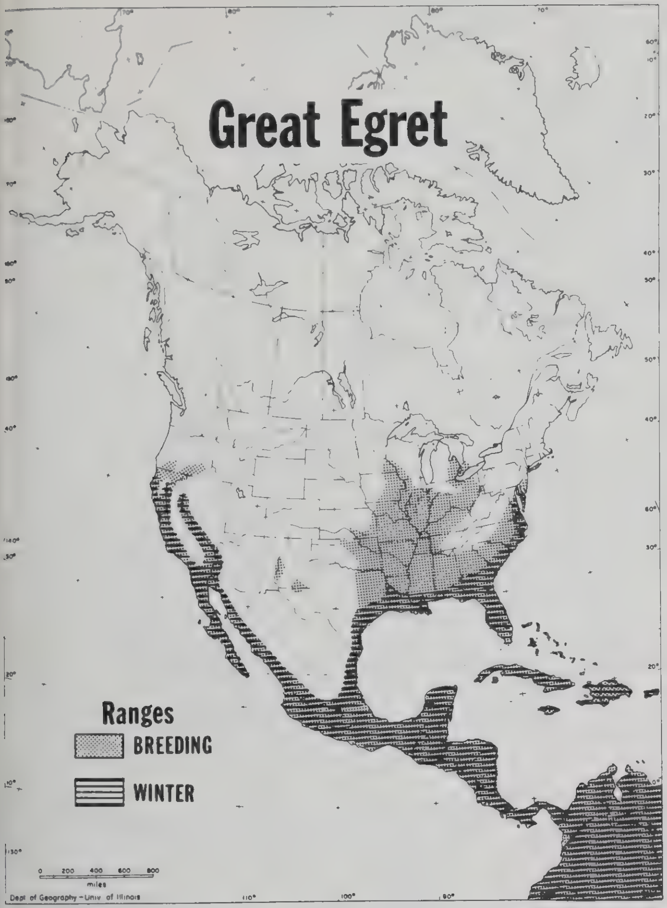

Fig. 28.—General distribution of the great egret. The species is also widely distributed in the Old World.

at first only as nonbreeding summer visitants. At Quincy, Musselman (1932*b*) saw the egret population climb notably after 1927. In the Mississippi valley north of St. Louis, Jones (1937*b*) reported the first egret nesting for the area in 35 years, and farther north on the Illinois River in 1938 Bellrose (1939*b*) found nesting great egrets near Peoria. By at least 1941 great egrets were nesting on the Mississippi in northern Illinois (DuMont & Smith 1946). The increase, both of the nesting and visitant populations, continued at least into the 1950's (Mayfield 1948, Nolan 1954*b*). Now (1970's) the Illinois nesting population appears to be declining, with many colonies being abandoned (Fig. 30). The seriousness of the decline is indicated by the recent counts of great egret nests in the state (Table 9). The counts of great egret nests censused in both 1973 and 1976 were 407 and 81, respectively—a decline of about 80 percent (27 percent per year). Not all colonies were censused in both 1973 and 1976, and if we use counts for consecutive years to obtain a more complete record, the number of nests for 1973 (plus data for four colonies in 1974) and 1976 were 455 and 91—also a decline of about 80 percent. In making this calculation, we had to exclude the number of great egret nests in colonies at East St. Louis, Old Monroe, Commerce, Grand Island, and Plainfield because counts were lacking for one or both sets of years. The Comment Sanctuary of East St. Louis was censused for birds, but not for nests, by members of the Southwest Chapter of the Illinois Audubon Society. If we use the number of adult great egrets as an index to number of nests, we estimate about 45 nests in 1973 and 5 in 1976. Other colonies not accounted for in the above totals were: Old Monroe, which had 25 nests in 1975 and none in 1976; Commerce, which had 1 nest in 1975 and none in 1976; Grand Island, which had 15 in 1975 and 10 in 1976; and Plainfield, which had 15 nests in 1973 (no data for 1976). These colonies account for an additional 101 nests, making a total of 556 great egret nests in the state in recent years (1973–1975), but not more than 106 (plus the Plainfield colony) in 1976. The record for 1977 is very incomplete but not encouraging as far as the egret population is concerned, as most of the counts that we do have are below the 1976 level.

The problem of evaluating the census data for the 1970's or any other short period involves not only the question of the accuracy of the census, but that age-old problem for biologists of a lack of long-term data on the "natural" fluctuations of wild populations. An 80-percent change in one direction over such a large area in 4 years seems excessive, but a number of high years could bring the population up as it did 40 years ago. Individual colonies have shown enormous variation. Harlan (1943 and 1945) saw the number of great egret nests at Sabula fall from 250 to 0 in 3 years. The number of nests at New Boston dropped almost as much between 1955 and 1957, but by 1963 was back to 100 nests and was down again to 25 by 1976 (Table 9). The nesting population of great egrets in the Illinois valley, 1958–1964, showed a strongly fluctuating pattern—375 nests in 1958, 640 in 1962, and 305 in 1964 (Mills et al. 1966). The range of variation is more than would be expected from natural mortality and productivity, given average mortality rates (76 percent for first year birds and 26 percent for older birds) for great egrets in the United States (Kahl 1963). The statewide counts (Table 9) also show more loss than would be expected from natural mortality, and it seems likely that the changes involve some movement. Though there is no proved case (based on banded birds) of the movement of a colony *en masse* to a new site, the case of the population at Grand Marais (Frank Holten) State Park is suggestive of such a move. When the nest trees in the park were cut in 1963, the birds abandoned the area, but by at least 1967 a similar population appeared only about 1½ miles away (Wrischnik 1973).

The decline of egrets in the last century was virtually continentwide, but, as yet, changes (if any)

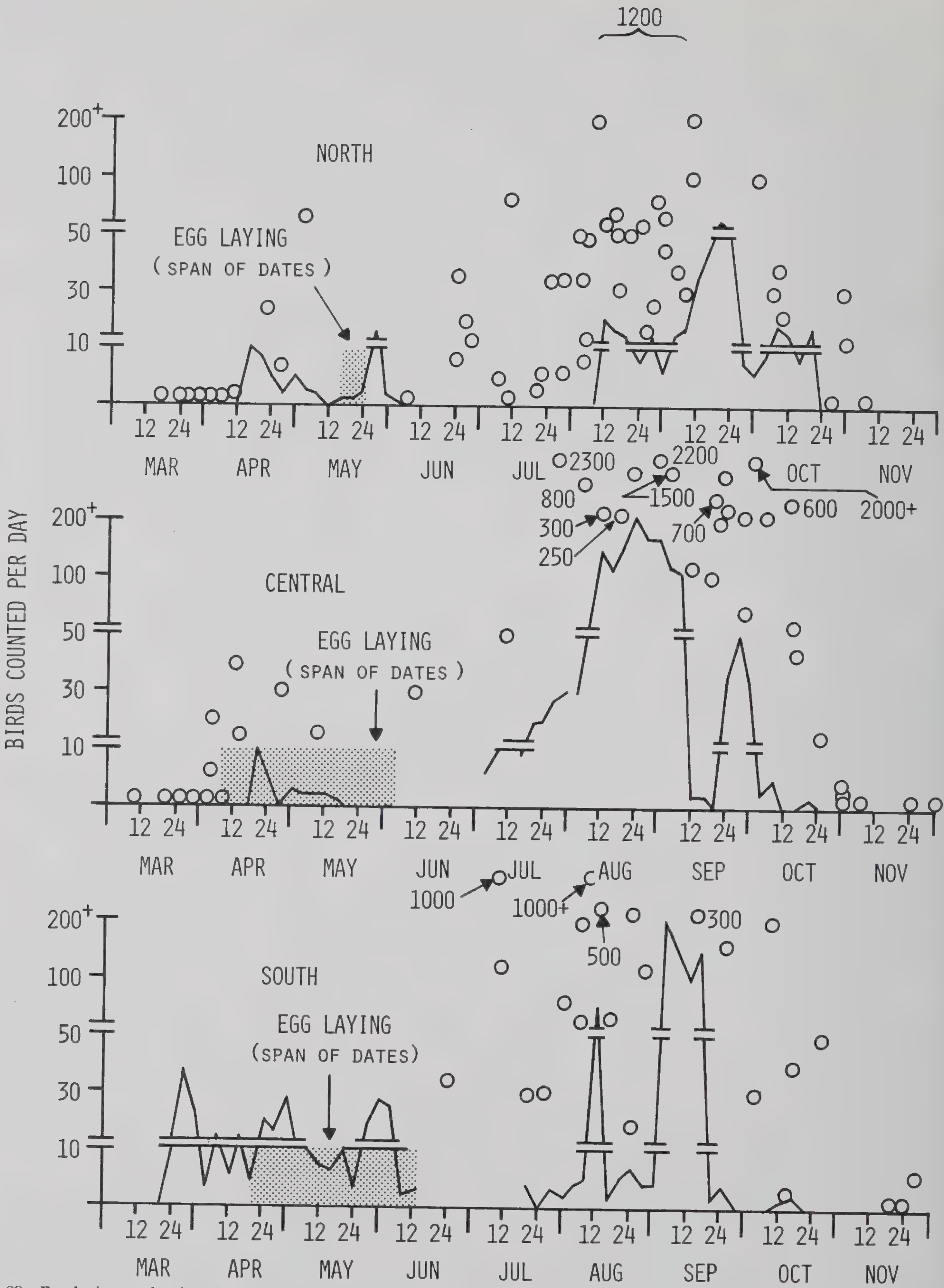

Fig. 29.—Egg-laying and migration seasons of great egret in different regions of Illinois. Spring and fall graph lines represent the highest daily count of each 4 days (1967–1970). Circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

Great Egret

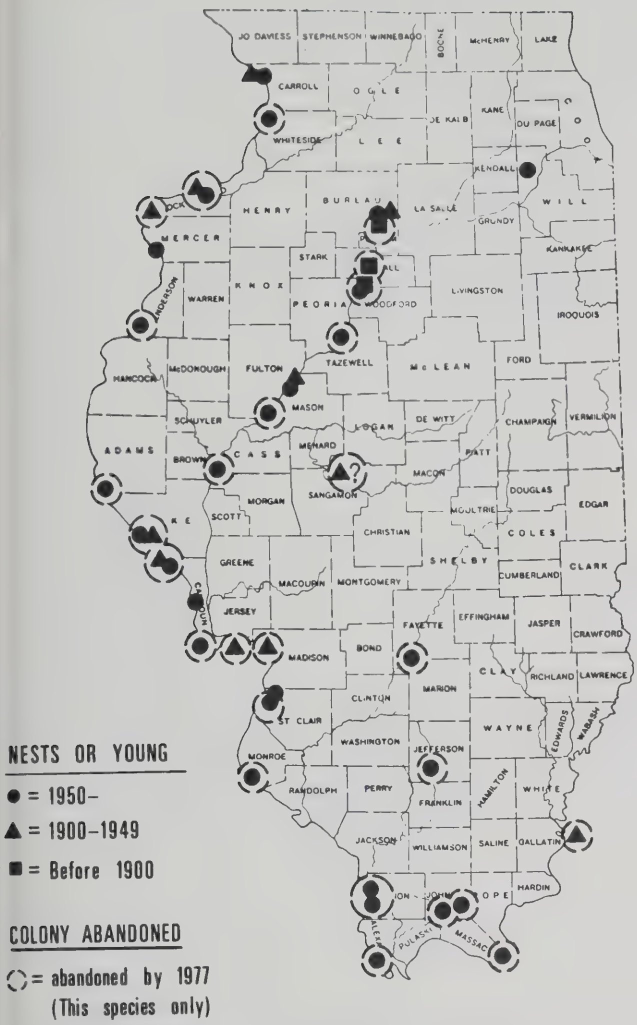

Fig. 30.—Distribution of nesting colonies of great egrets in Illinois. Encircled colonies were apparently abandoned by 1976–1977.

in the total continental population are apparently unknown.

We have some evidence that egrets are showing indications of hydrocarbon pollution (see also the introduction and the great blue heron account). A total of 47 measurements of the shells of nine great egret eggs, presumed to have hatched, from the Hamburg colony showed a range of shell thickness of 190–289 microns and a mean of 252 (SE = 3.61). This mean was thinner than that of pre-1947 eggs (mean: 295 microns) and was about comparable to the thickness of recently measured great egret eggs from California (range of means: 244–272 microns, Faber et al. 1972).

Nesting Cycle

The nesting cycle of the great egret is poorly known in general (Palmer 1962), and there are very few Illinois data. Anderson (1963*a*) recorded the arrival of 15 great egrets at a colony site at East St. Louis by 31 March with 31 of 50 nests occupied by 7 April. Farther north at Rock Island, Hodges (1953) found the first birds in the colony on 5 April.

Nest building by egrets and night herons was noted by Galbreath (1962) at East St. Louis on 5 May. We have seen egrets carrying sticks to the nest as late as 30 June at Hamburg, but we presumed this to be refurbishing, not initial building. The time required for nest building is unknown.

The eggs are pale blue or greenish blue, often more richly colored than great blue heron eggs. Laying frequency and clutch size are unknown for any Illinois population. We have estimated the egg-laying period to extend from at least 20 April to 14 June in southern Illinois (Fig. 29), based on fledging dates and an incubation period of 25 days and nestling life of 42 days (Palmer 1962). The 14 June date was based on hatching observed on 9 July 1975. In central Illinois, Bjorklund (unpublished) detected egg laying as early as 5 April.

At East St. Louis fledged young have been seen as early as 14 July (Galbreath 1962), and young still in the nest as late as 14 August (Mumford 1960*a*). In northern Illinois we've seen birds in nests on 1 August but do not know how much later they remained.

Hatching rate, nesting success, and productivity are not known for any Illinois population and are badly needed to help interpret the falling population. Our *best* counts (from the ground) of well-grown young at 188 nests throughout the state between 1973 and 1976 were 2.5 and 2.2 per nest (for sources of error in this type of data, see under great blue heron). From mortality data on great egrets in the USA, Kahl (1963) calculated that 2.9 young per pair are needed to maintain a population.

Near Rock Island, Hodges (1950) noted signs of molting, including the loss of plumes, by 19 June, but the molt was much more evident on 16 July. Near Peoria, Bellrose (1939*b*) observed that the egret's plumes were badly worn by 8 July and completely gone (molted) by 27 July. At Sabula, Harlan (1943) noted large numbers of shed plumes on 30 July. The duration of the molt has not been recorded.

Fall Migration

The arrival of great egrets in summer, mainly from the south (Coffey 1943), is often conspicuous because of the pronounced population increases. Whether birds breeding in Illinois also move northward after breeding is not established, but the history of a bird banded as a fledgling on 3 July 1963 at Pekin and recovered on 1 November 1965 at Zion is suggestive of such movement (Bjorklund & Canterbury 1971). The postbreeding flights carry some

Table 9.—Great egret colonies in Illinois and adjacent areas.

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
			Mississippi River Area						
Sabula, Iowa	Jackson	1941	10	DuMont & Smith (1946)					
Sabula, Iowa	Jackson	1942	10	DuMont & Smith (1946), Hodges (1947)					
Sabula, Iowa	Jackson	1943	250	Harlan (1943)					
Sabula, Iowa	Jackson	1944	"small number"	Harlan (1945)					
Sabula, Iowa	Jackson	1945	0	Harlan (1945)	...	4	2	10[a]	...
Clinton	Whiteside	1966	2	W. H. Brown (1966)	...	0	0	0	...
Iowa (location?)	Scott	1948	P[b]	Mayfield (1948)					
Andalusia	Rock Island	1948	P?	Hodges (1950)					
Andalusia	Rock Island	1949	25[c]	Hodges (1950)					
Andalusia	Rock Island	1950	Fewer than in 1949	Hodges (1950)					
Andalusia	Rock Island	1965	P	Petersen & Ward (1966)					
Andalusia	Rock Island	1966	50[c]	Petersen & Ward (1966)	0	0	3	0	0
Iowa (location?)	Muscatine	1948	P	Mayfield (1948)	0	0	0	0	...
Iowa (location?)	Louisa	1948	P	Mayfield (1948)	0	0	0	0	...
New Boston	Mercer	1955	250[c]	Greer (1955)					
New Boston	Mercer	1956	200[c]	Nolan (1957)					
New Boston	Mercer	1957	30[c]	Nolan (1957)					
New Boston	Mercer	1958	P	Nolan (1958*b*)					
New Boston	Mercer	1959	50	Mumford (unpublished)					
New Boston	Mercer	1960	P	Mumford (1960*c*)					
New Boston	Mercer	1962	67	Brown (1962)					
New Boston	Mercer	1963	100	Brown (1963*b*)	50	25	5	15	25
Burlington, Iowa	?	1942–1943	P (2 years)	Musselman (unpublished)					
Skunk River, Iowa	Des Moines				20	4	0	0	...
Quincy area	?	1948	P (4 colonies)	Mayfield (1948)					
McDonald Island	Adams				20	0	0	0	...
Atlas	Pike	1948	150	Musselman (unpublished)	0	0	0	0	...
Boyd Island	Pike				...	40	4	0	...
Clarksville No. 1, Mo.	Pike	1941	P	Jenkins (1942)					
Clarksville No. 1, Mo.	Pike	1942	P	Jenkins (1942)	0	0	0	0	...
Clarksville No. 2	Calhoun	1942	100	Cunningham & Spotswood (1942)	0	10	0	0	0
Hamburg	Calhoun				150	190	75	35	10
Miss. R. Islands, Mo. (location?)	Lincoln	1900	P	Widmann (1907)					
Miss. R. Islands, Mo. (location?)	St. Charles	1900	P	Widmann (1907)					
Old Monroe, Mo.	St. Charles				...	...	25	0	...
Marais Temps Clair, Mo.	St. Charles	1935	1	Jones (1937*b*)					
Alton	Madison?	1941	12	Cunningham (1941)					
Grand Marais (East St. Louis)	St. Clair	1958	15	Nolan (1958*b*), Comfort (1958*b*)					
Grand Marais (East St. Louis)	St. Clair	1959	25–30	Comfort (1959), Mumford (1959)					
Grand Marais (East St. Louis)	St. Clair	1961	25–50	Comfort (1961*b*), Galbreath (1961)					
Grand Marais (East St. Louis)	St. Clair	1962	43	Anderson (1962*a* and *b*)					
Grand Marais (East St. Louis)	St. Clair	1963	50	Anderson (1963*a* and *b*)					
Grand Marais (East St. Louis)	St. Clair	1964	P	Anderson (1964*a*)	0	0	...	...	...

(Table 9 continued on next page.)

TABLE 9.—Continued

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests 1973	1974	1975	1976	1977
East St. Louis (Comment Sanctuary)	St. Clair	1964	P	Wrischnik (1973)					
East St. Louis (Comment Sanctuary)	St. Clair	1967–1976	P	Wrischnik (1973, 1975–1976), Kleen (1974–1975, 1976–1977)					
Fults	Monroe	1971?	P	Fleig (1971)	0	40	40	5	0
Wolf Lake	Union	1950	P	Lopinot (1950)	0	0	0	0	. . .
Ware	Union				100	80	10	1	0
Commerce, Mo.	Scott				. . .	. . .	1	0	. . .
				Illinois River					
Depue	Bureau	1941	25	Smith (1941)					
Depue	Bureau	1942	P	Bartel (1943)					
Depue	Bureau	1946	20	DuMont (1947*b*)					
Depue	Bureau	1947	50	DuMont (1947*b*)					
Depue	Bureau	1958	250	Bellrose (unpublished)					
Depue	Bureau	1962	300	Bellrose (unpublished)					
Depue	Bureau	1964	120	Bellrose (unpublished)					
Depue	Bureau	1967	140	Bellrose (unpublished)	20	15	15	10	1
Depue-Hennepin area	Putnam?	1890	P	Barnes (1890*b*)					
Hennepin Lake	Putnam	1907	6	Barnes (1912)					
Lacon (12 km south)	Marshall	1879	P	Barnes (1909)					
Marshall County (location?)	Marshall	?	P	Barnes (1917)					
Chillicothe	Peoria?	1891	P	W. E. Loucks (unpublished)	. . .	1	1	0	0
Pekin	Tazewell	1958	125	Bellrose (unpublished)					
Pekin	Tazewell	1962	34	see Bjorklund (1975) for complete record					
Pekin	Tazewell	1967	128	Bjorklund (1975)					
Pekin	Tazewell	1968	49	Bjorklund (1975)					
Pekin	Tazewell	1972	58	Bjorklund (1975)	2	0	0	0	0
Big Lake	Fulton	1938	1	Bellrose (unpublished and 1939*b*)	. . .	0	0	0	. . .
Clear Lake	Mason-Tazewell	1958,1962	0	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1964	110	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1967	170	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1968	327	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1969	293	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1971	82	Bellrose (unpublished)					
Clear Lake	Mason-Tazewell	1972	70	Bjorklund (unpublished)	30	. . .	29	15	36
Grand Island	Mason	1973	P	Bellrose (unpublished)	. . .	. . .	15	10	0
Meredosia	Cass	1973	P	Bellrose (unpublished)	. . .	0	0	0	0
				Localities Other Than Mississippi and Illinois Rivers					
Kankakee River, Ind.	Lake?	1907	P	Woodruff (1908)	. . .	. . .	. . .	. . .	0
Plainfield	Will	1961	P	Fawks & Lobik (1975)					
Plainfield	Will	1970	P	J. R. Sanders (unpublished)					
Plainfield	Will	1971	10	J. W. Olson (unpublished)	15	. . .	. . .	. . .	16
Willow Slough, Ind.	Newton	1953	10	Ginn (1954), Nolan (1953*c*)					
Willow Slough, Ind.	Newton	1954	20	Nolan (1954*b*), Mumford (unpublished)					
Willow Slough, Ind.	Newton	1959	0	Mumford (unpublished)					
Springfield, Sangamon River	Sangamon	1945	P?	DuMont & Smith (1945)	. . .	. . .	. . .	0	. . .
Hovey Lake area, Ohio River, Ind.	Posey	1945	P?	Skaar (1951)	. . .	. . .	. . .	0	. . .

(Table 9 continued on next page.)

Table 9.—Continued

Colony Site	County	Year	Number of Nests	Reference	Recent Counts of Nests				
					1973	1974	1975	1976	1977
Shobonier, Kaskaskia River	Fayette				0	1	0	0	...
Rend Lake, Big Muddy River	Jefferson				3	6	0	0	...
Grantsburg, Bay Creek	Johnson	1966	P	J. Schwegman (unpublished)					
Grantsburg, Bay Creek	Johnson	1969	0	J. Schwegman (unpublished)	0	0	0	0	...
Heron Pond, Cache River	Johnson	1969	22	J. Schwegman (unpublished)	12	0	0	0	...
Unionville, Ohio River	Massac				...	3	0	0	...
Number of nests counted, 1973–1976					423	419	225	101	
Number of colonies with egrets					11	10	13	8	

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[a] Counts above 5 rounded to nearest 5.
[b] Nests present but not counted.
[c] Number calculated from author's data.

birds as far north as Canada. Before egrets bred commonly in Illinois, the appearance of the summer transients was especially conspicuous. Musselman (1933 and 1937) noted such arrivals at Quincy on 14 and 26 July. Nelson (1877) observed that egrets became common at Mt. Carmel by the last of July. Bellrose (1939*a*) noted the beginning of the influx—22 birds—on 3 July at the mouth of the Illinois River, and observed 120 egrets by 10 July.

There is great annual variation in these summer-fall flights not only in the numbers seen, but in the arrival and departure dates. Especially large flights were recorded in 1938 (Bellrose 1941) and 1947 (Cunningham 1948); the observation of 1,000 birds on 9 July 1947 at Cape Girardeau is early for such a number, but by 1 August several thousand were present. A high count of 2,300 birds on 28 July at Lake Chautauqua (Smith 1942*b*) also represents the influx of transients. These were presumably counts of foraging birds, but such counts at a single place do not usually exceed a few hundred birds in most years (Fig. 29). These flights may be diurnal at least in part. Both Robert Russell (see Mumford 1961*c*) and Peter Dring have observed northward flights of flocked egrets in August—one flock in "V" formation flying along the shore of Lake Michigan.

Egrets are very social and form communal roosts from the time of their first arrival in spring (Stewart 1949). The late summer roosts are particularly impressive, and counts at such locations may exceed 1,000 birds. Bellrose (1939*a*) estimated that about 7,000 great egrets roosted in the Illinois Valley at seven sites between Depue and Meredosia in 1938. The roosts were in bottomland forests, often near the nesting colony sites of great blues and night herons. One roost in the Mississippi Valley was in a buttonbush marsh (Short 1938). Bellrose (1939*a*) saw the roosting population decline sharply in late September, and by 15 October only 45 birds were left at Chillicothe. The variation in our fall counts (Fig. 29) may represent annual rather than regional variation, but most egrets have migrated south of Illinois by the end of October. Relatively few linger into November or later, and they probably do not do so every year. Sarah Vasse reported November sightings of great egrets in 2 of 3 years in Calhoun County (Petersen 1964 and 1966*a*). The detailed characteristics of the fall migration are not known with certainty and may be different from those of the northward summer flights (see above). A departure of egrets from Calhoun County was noted to coincide with the passage of a cold front on 2 November 1963 (Anderson 1963–1964). Musselman (1932*a*) implied that the fall flights were nocturnal, probably on the basis of overnight population changes, but no fall migration flights of any kind had been witnessed.

The great annual differences in summer egret populations have been attributed to weather. Stewart (1949) suspected that low-water years had high egret populations, but high transient populations in August have also been attributed to floods in July (Short 1942), and low populations to drought (Blake 1948*a*). Two notably high "egret years"—1938 and 1947—had very different weather except in June, when both had high precipitation. The factors that affect heron populations include all the factors that affect fish populations and their availability in Illinois and elsewhere. On 22 October 1956 on a flight over the Illinois and Mississippi rivers between Depue, St. Louis, and Rock Island, we counted about 1,300 egrets, nearly all in the Illinois Valley, which offered many more shallow lagoons than the Mississippi. In 1969 also—the only other year when we made comparative counts—our (ground) counts were much higher in the Illinois than in the Mississippi Valley. There was also a marked difference in the egret population between western and eastern Illinois, even in the south where the Ohio and Wabash rivers might seem to provide habitat attractive to the birds. In the south we saw 4.4 great egrets in the west to 1.0 in the east in spring, and 30.5 to 1.0 in fall. The summer influx thus seems much more strongly associated with the Mississippi than with the Ohio drainage. East-central Illinois has probably the lowest populations of transient egrets compared with those of the west, with the ratio on the order of one in the east to several hundred in the west. We have no east-west ratio for northern Illinois, but would expect it to favor the west strongly. Eastern wetlands

TABLE 10.—Food collected from nestling great egrets at six Illinois heron colonies on the Mississippi and Illinois rivers 5 July–1 August 1973–1975.

Food Item	Number of Specimens			Total Specimens	Percent of Total	Estimated Weight of Food (Grams)	Percent of Weight
	Illinois River	Mississippi River					
	Depue	New Boston	Hamburg-Ware				
Crayfish (*Orconectes virilis)*	0	0	2	2	0.4	14	1.0
Shortnose gar (*Lepisosteus platostomus)*	0	0	2	2	0.4	20	1.4
Gar (*Lepisosteus* species?)	0	0	2	2	0.4	55	3.9
Bowfin (*Amia calva)*	0	0	1	1	0.2	25	1.8
Gizzard shad (*Dorosoma cepedianum)*	23	39	278	340	71.0	850	60.5
Carp (*Cyprinus carpio)*	0	0	20	20	4.2	100	7.1
Emerald shiner (*Notropis atherinoides)*	15	26	0	41	8.6	37	2.6
Smallmouth buffalo (*Ictiobus bubalus)*	0	2	0	2	0.4	4	0.3
Bigmouth buffalo (*I. cyprinellus)*	0	13	12	25	5.2	75	5.3
Black bullhead (*Ictalurus melas)*	0	0	1	1	0.2	4	0.3
Brown bullhead (*I. nebulosus)*	0	0	2	2	0.4	16	1.1
White bass (*Morone chrysops)*	0	18	0	18	3.7	36	2.6
Yellow bass (*M. mississippiensis)*	0	0	4	4	0.8	8	0.6
Green sunfish (*Lepomis cyanellus)*	0	0	2	2	0.4	2	0.1
Bluegill (*L. macrochirus)*	0	2	4	6	1.2	27	1.9
Sunfish (species?)	1	0	0	1	0.2	2	0.1
Largemouth bass (*Micropterus salmoides)*	0	0	5	5	1.0	100	7.1
White crappie (*Pomoxis annularis)*	0	0	4	4	0.8	12	0.8
Black crappie (*P. nigromaculatus)*	0	0	1	1	0.2	17	1.2
Total	*39*	*100*	*340*	*479*	*99.7*	*1,404*	*99.7*

do attract large numbers of egrets in some years—as many as 500 having been seen at Willow Slough (Nolan 1952).

The ratio of our spring (March–May) to fall (July–October) counts of great egrets was 1.0 to 12.9 for the entire state, including the data for central Illinois, which had an exceptionally low spring count in 1969 (Fig. 29). The ratio for northern Illinois was 1.0 in spring to 11.2 in fall, and for southern Illinois, 1.0 to 8.1. As the best age ratio we observed was 1.0 adult to 1.25 young at fledging age, the high fall ratio strongly reflects the summer influx.

Food

The food items taken by great egrets appear to be very similar to those used by great blue herons but with a much higher proportion of gizzard shad in the egret's diet (Tables 4 and 10). Also important as egret food were carp, emerald shiner, bigmouth buffalo, and bass. Galbreath's (1961) list of prey species seen at East St. Louis (a colony we did not visit) is very similar to ours for six other colonies on the Mississippi and Illinois rivers (Table 10).

From the lists of prey species, one might suspect that the great blue heron and great egret are strongly in competition for food for their respective young, but the two species appear to be catching different age-classes of fish. The egrets start nesting about 3 weeks later than do the great blues, and though the egret's nesting cycle is about 10 days shorter, the egret's young are generally well behind the young of great blue herons in size. Food size increases as the young herons grow (Lopinot 1950), and we found food items from egrets to be consistently smaller than those from great blues in the same colony on the same date. For example, specimens of gizzard shad—the most important food species for both herons and egrets—varied from 25 to 305 mm in length (mean: 142 mm) from great blue heron young, and from 38 to 178 mm (mean: 61 mm) from egret young. The measurements indicate that egrets are feeding mainly on shad young of the year, when great blues are taking yearling shad (see Miller 1960 for growth data on fish).

Data on the food of adult egrets are lacking. Franzen (1934) observed that egrets stayed later in the evening (by 1½ hours) than great blues to forage before going to roost. Though egrets characteristically fish from a standing position, Hodges (1947) saw one hover briefly in flight and drop into the water to pick up food.

Winter Records

Musselman (*in* Mumford 1961*a*) referred to great egrets wintering near Quincy, but we have seen no other record showing that egrets spend the winter in Illinois. Though there are a few late December (27, 28) records as far north as the Princeton area, presumably on the Illinois River (Dyke 1953, Kramer 1957 and 1962), and a 30 December record for Cape Girardeau (Anonymous 1949), we have found no January record for the great egret in Illinois. The species is apparently much less cold tolerant than is the great blue heron.

SNOWY EGRET *(Egretta thula)*

(Fig. 31 and 32)

Spring Migration

To some extent the observed timing of events in a population is a function of the size of the population (as is the number of observations)—larger populations showing great latitude in all measurable characters, including the timing of migration. The snowy egret population in Illinois is relatively small. The earliest report for the area known to us is 2 April in adjacent Indiana (Keller 1966), but the snowy is not usually sighted in Illinois before mid- or late April (Fig. 33, Cooke 1888, Anderson 1964*a*, Petersen 1968*a*). There is little obvious variation in its arrival in different regions of the state, and the appearance of a few snowies in the north, where they

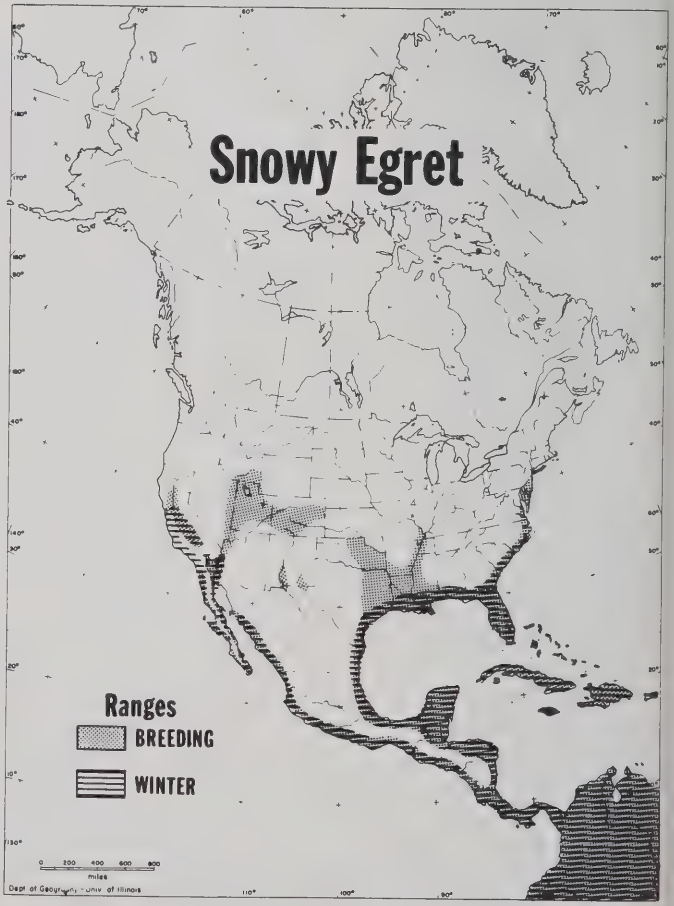

Fig. 31.—General distribution of the snowy egret.

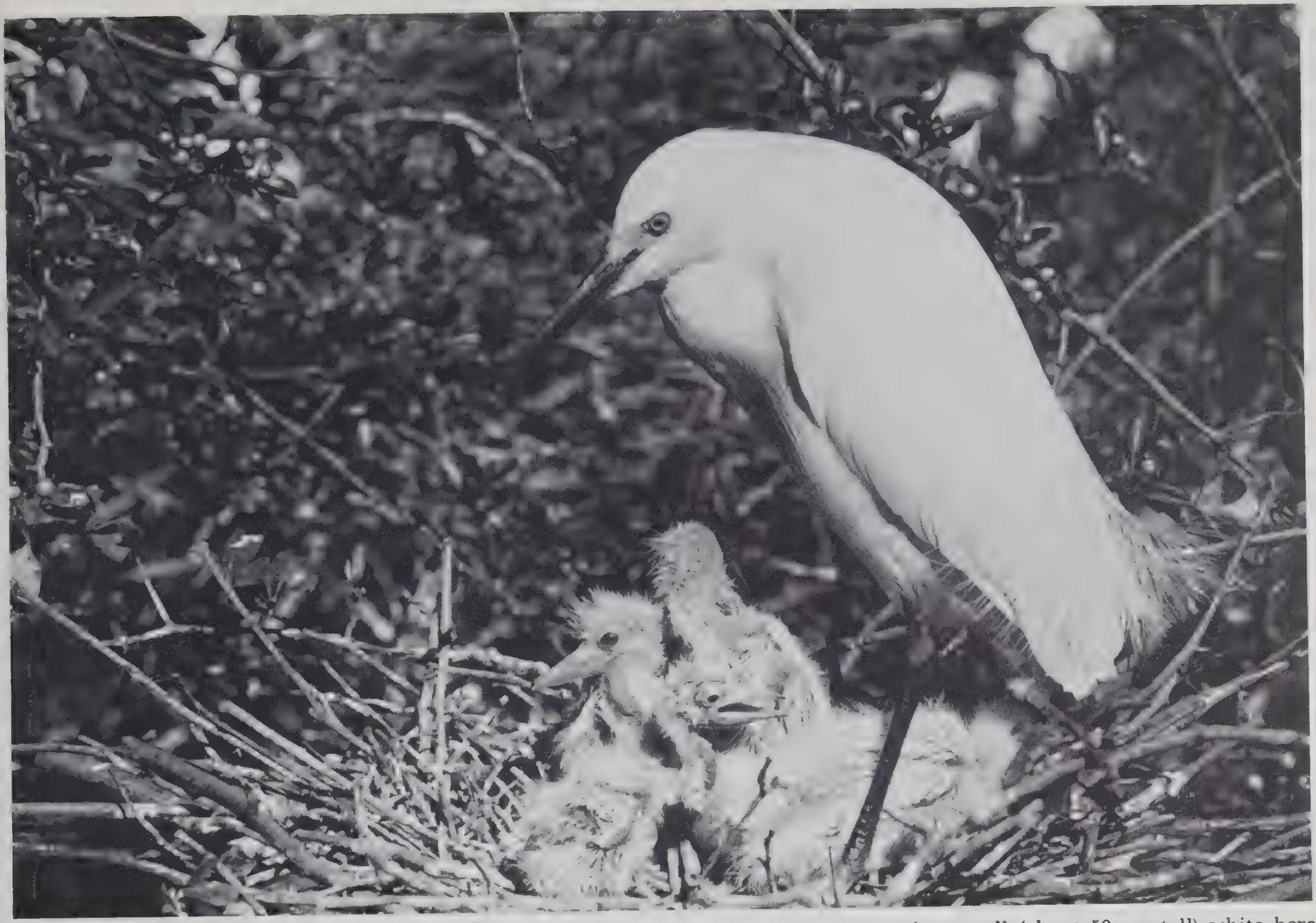

Fig. 32.—Adult snowy egret attending its nestlings at Comment Sanctuary. The snowy is a small (about 50 cm tall) white heron with black bill and legs and yellow feet (barely visible at bottom of picture). Note abundant aigrette plumes on the back. Photograph by Robert Starr.

are not known to breed, suggests the possibility that the birds are overflying northward during night migration. The peak in late April (Fig. 33) and the relatively small number of records in May are also suggestive of this possibility though Anderson (1964*a*) noted that snowies were seen commonly after 25 April in the Mississippi bottoms south of St. Louis, where they probably do nest. Highly plumed birds have been reported on 27 May and later (Comfort 1957, Anderson 1962*a* and 1964*c*).

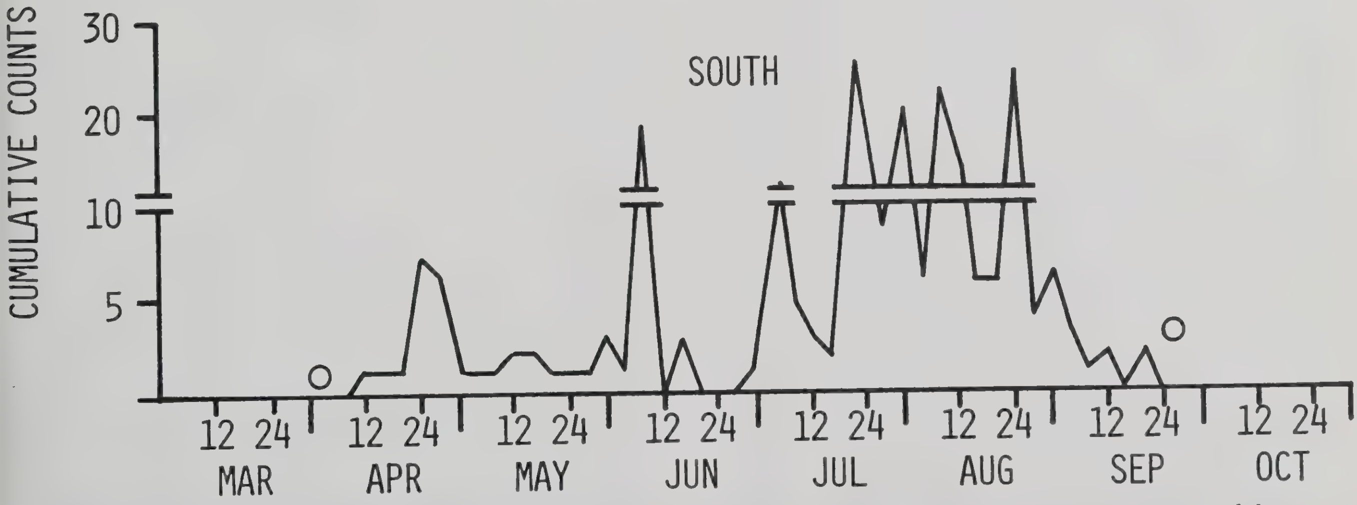

Fig. 33.—Cumulative counts by all observers of snowy egrets in southern Illinois. Circles represent the earliest and latest records for the state.

Distribution

The snowy egret nests primarily in the southern United States and Central and South America (Fig. 31). In Illinois the only known recent nestings are in or near the Mississippi Valley (Fig. 34) north as far as Pike County (William H. Elder unpublished). Butler's (1897) reference (from Ridgway) to breeding records for the snowy egret in adjacent Knox and Gibson counties, Indiana, cannot be substantiated, nor can Kennicott's (1853–1854) record for Cook County, Illinois. Bent's (1926) reference to snowy egrets breeding north of Peoria is also enigmatic, since no nests of the species have been discovered in the Illinois valley.

The unquestioned nest records are all recent, mainly from the East St. Louis area (Fig. 34, Petersen 1970, Kleen 1975*b*). It is unclear from Fleig's (1971) report whether he actually found nests in the Fults area. Neither Hurter (1884) nor Widmann (1907) knew of nest records for the snowy egret in the St. Louis area. In fact, there were apparently no records of any kind for snowies in the area until 1934 when Jones (1935) reported them as plentiful (see also Short 1942). Nonbreeding snowy egrets appear widely in the state, especially in late summer and fall (Fig. 34), but, proportionate to the number of observers, at all seasons there are many more records of this species in the southern region of the state than there are in the central and northern regions.

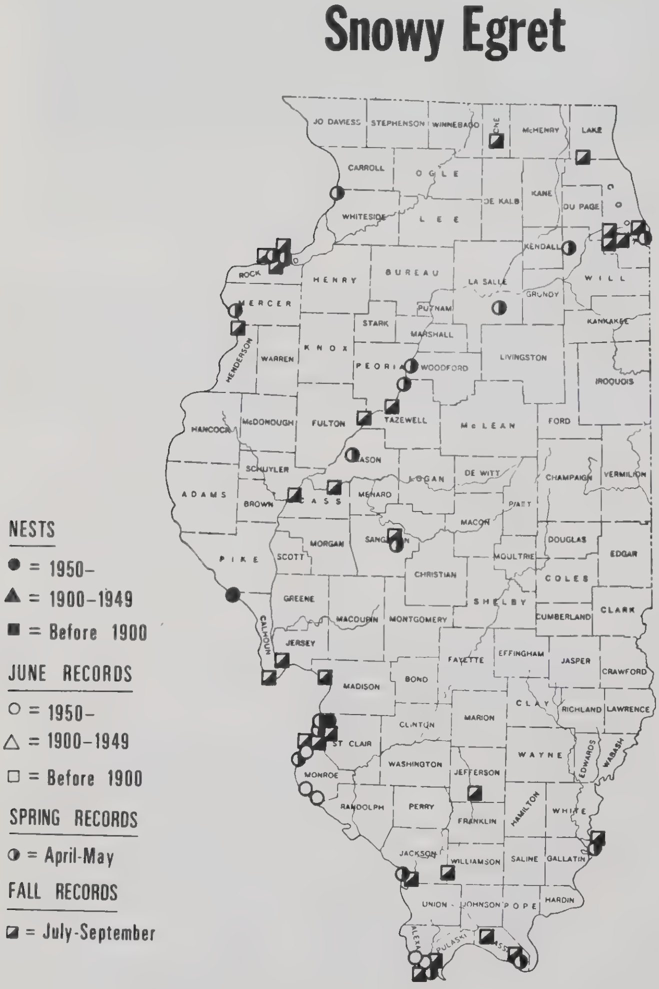

Fig. 34.—Distribution of records of snowy egrets in Illinois.

Nesting Habitats and Populations

There are virtually no data on the nesting or foraging habitats of snowy egrets in Illinois. Snowy egret nests in Illinois have always been associated with those of other species of colonial herons, especially little blues, in lowland thickets or forest. In Alexander County, Michael Morrison (unpublished) observed snowies foraging in very shallow (5 cm) water.

The largest number of snowies recorded nesting in one place (East St. Louis) in the state was four pairs (Petersen 1970). The number of snowy egrets in the Comment Sanctuary is small and variable, and apparently, the species is absent there in more years than it is present (Wrischnik 1973 and 1975–1976, Kleen 1974–1975 and 1976–1977). There are no absolute population measurements for the snowy egret in any area of Illinois, but the total breeding population is probably less than 50 birds in a high year. An undated reference to "thousands" of snowies on the Illinois River (H.F.A. 1889) is almost certainly a case of misidentification. The highest 1-day count of snowies in June (6 June 1977) was 18 in Alexander County (Michael Morrison unpublished), and more often only 1–3 per day are reported.

The destructive work of the plume hunters in the 19th and early 20th centuries greatly reduced the entire U.S. population of snowy egrets (Cooke 1913), and the species apparently disappeared completely from Illinois and vicinity (Widmann 1907). There were very few Illinois records between 1890 and 1930, but the population gained greatly in the 1930's and 1940's (Jones 1935, Cunningham 1947). There is no evidence, however, that there was ever a large breeding population (i.e., more than a few pairs) in Illinois.

Nothing has been recorded on the nesting cycle in Illinois.

Fall Migration

Snowy egrets, like great egrets and several other herons, appear to move northward after the nesting season, and the fall population is much greater than the spring population in Illinois (Fig. 33), reflecting the influx of birds from more southern breeding grounds. Banding records are not available to show the precise sources of snowies that come to Illinois. The influx probably begins in July, and the number of birds remains relatively high through most of August (Fig. 33), depending probably on the availability of suitable foraging areas. In late August and early September, snowies definitely begin to leave the state, and few are seen after 12 September (Fig. 33). The latest record known to us is 27 September (Bellrose 1941). The late summer numbers vary greatly from year to year, with concentrations as high as 20–30 birds having been reported in some years (DuMont 1932, Nolan 1952) though such numbers are exceptional for the species in Illinois. Jones (1935) suggested that an apparent abundance of snowy egrets might be related to extensive drought that concentrated the birds where water remained.

LOUISIANA HERON
(Hydranassa tricolor)

There was only one report of the Louisiana heron for Illinois before 1968. One was seen at Jackson Park, Chicago, on 22–23 May 1939 (Levy 1940, Ford 1956). In 1968 an adult was observed between 2 June and 6 July near Fults, Monroe County, on the Illinois levees of the Mississippi River (Petersen 1968*b*, Hamilton 1969). In 1969 a Louisiana heron was seen in Illinois across the Mississippi River from Cape Girardeau on 28 June (Anderson 1971*a*). In 1974 one was photographed at Ware, Union County, on 23 April, and one was seen in Illinois near St. Louis on 23 May (Anderson 1974*a*, Kleen 1974*e*). In 1976 Louisiana herons were reported at East St. Louis from 24 April to 30 April, at Waukegan from 27 June to 4 July, and at Springfield Lake, Sangamon County, on 4 and 5 October (Kleen 1976*d* and 1977*a*). One was seen at Waukegan on 18 April 1977 (Kleen 1977*b*). The increased incidence of sightings of Louisiana herons may be the result of some ecological change, but it may also result, in part, from more trained observers being in the field.

BLACK-CROWNED NIGHT HERON
(Nycticorax nycticorax)

(Fig. 35 and 36)

Spring Migration

A few black-crowned night herons sometimes winter in Illinois, but the first signs of the spring migration are not usually seen before 20 March or, more often, early April (Fig. 37). McCarty (1928) reported that these birds arrived at a Tuscola colony quietly during the night, between 8 and 15 April in various years. In the Mississippi Valley near St. Louis night herons arrived at one colony by 19 March (Jones 1939*a*) and at another by 31 March and 4 April in different years (Comfort 1958*a*, Anderson 1963*b*). In the north (Plainfield) Gossmann saw 6 black-crowns on 31 March and 146 on 12 April (Fawks 1966*b*). The migration is presumed to be nocturnal. We have heard migrant night herons flying at night over east-central Illinois between 28 March and 30 May, with maximum calling heard between 12 April and 24 May. The calls were heard at all hours of the night (7:00 pm–5:00 am) with no particular mode.

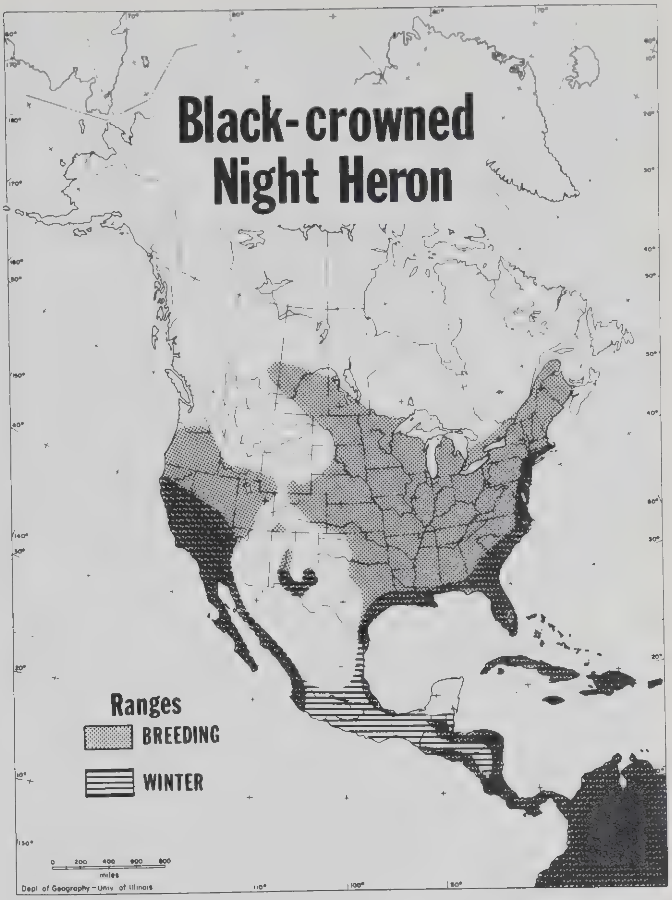
Black-crowned Night Heron
Ranges
▨ BREEDING
☰ WINTER
0 200 400 600 800
miles
Dept. of Geography—Univ. of Illinois

Fig. 35.—General distribution of the black-crowned night heron.

Distribution

The black-crowned night heron has a nearly worldwide distribution, including much of North and South America (Fig. 35). In Illinois the distribution is poorly known, partly because of the species' rather secretive nature. The absence of breeding records from much of the south (Fig. 38) is puzzling but may merely reflect the shortage of observers in the region. Ridgway (1895) and Nelson (1876 and 1877), who knew the birds of southeastern Illinois, were peculiarly mum about the black-crowned night heron in southern Illinois, as was Barnes (1912) in Marshall County, and Musselman in Adams County. Gross (1923) referred to small nesting colonies on the Wabash drainage, but did not give specific localities. Because night herons nest singly as well as in colonies, their nests can be easily overlooked. Even small colonies can be well concealed. Harold M. Holland (unpublished notes) referred to an old colony in Stark County (location ?). The black-crowned night heron is known from Indian middens only from the Peoria

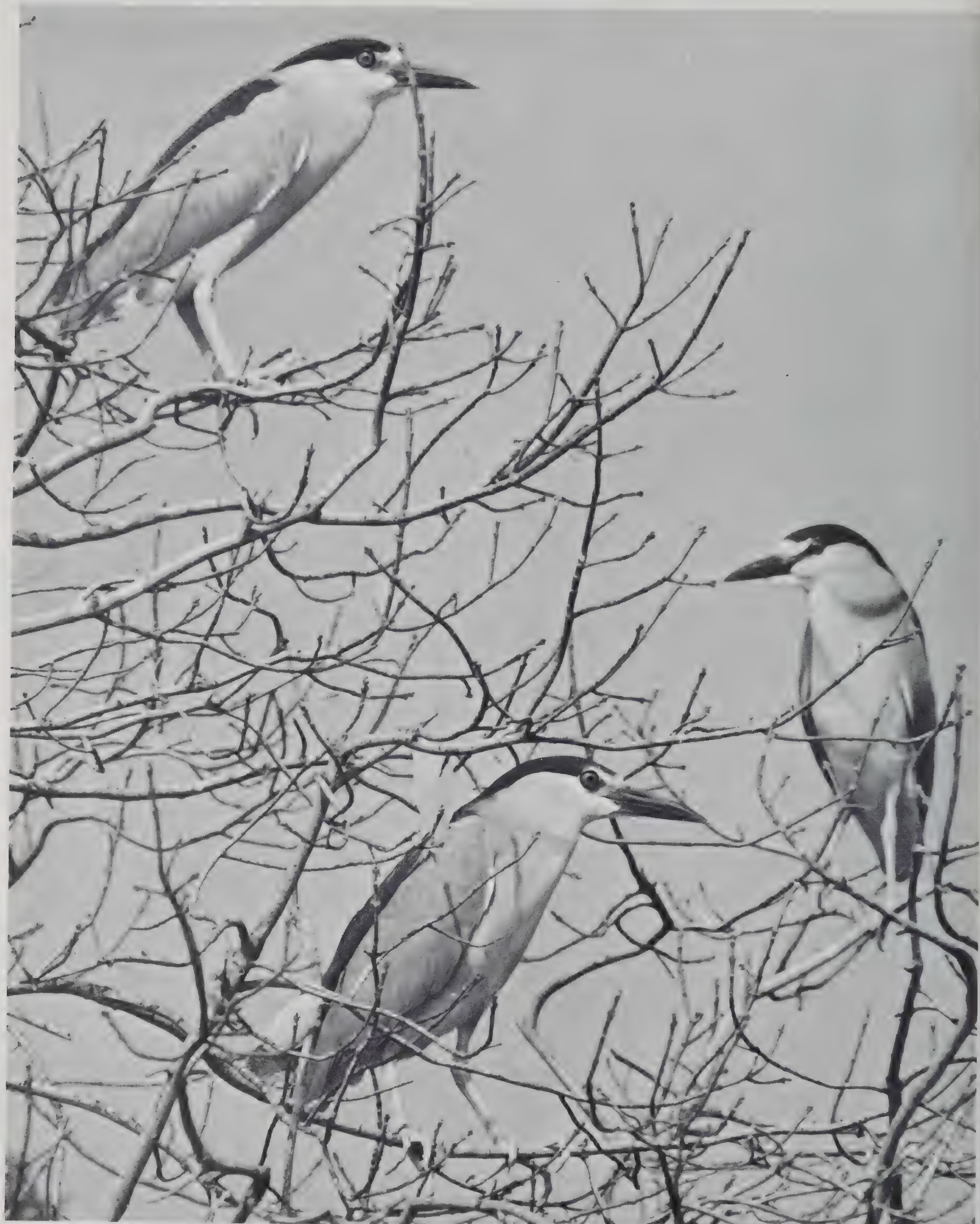

Fig. 36.—Adult black-crowned night herons. They are rather short, squat (about 50 cm tall) herons with black backs and white underparts.

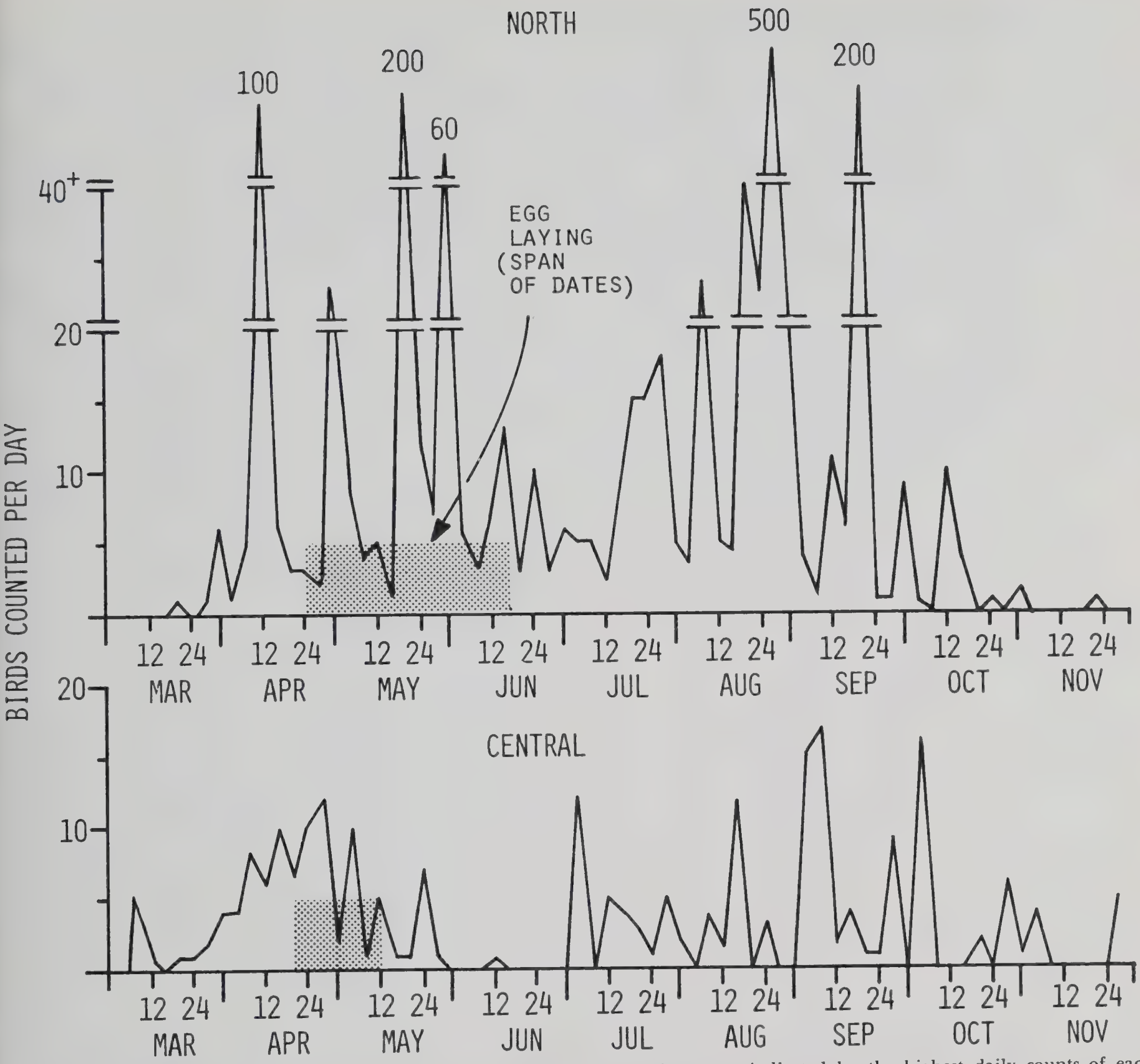

Fig. 37.—Egg-laying and migration seasons of the black-crowned night heron, as indicated by the highest daily counts of each 4 days by all observers in north and central Illinois. Too few counts exist for southern Illinois to graph them. Shaded areas show the span of dates during which egg laying has been recorded.

area, dating back to about 1100 AD (Baker 1936 and 1941, Parmalee 1962*a*).

Nesting Habitats and Populations

Black-crowned night heron nesting colonies have been found in a variety of arboreal habitats, from upland orchards (Gross 1923) to extensive bottomland forests and even towns and cities (Cunningham 1945, Farwell 1919). A very different nesting habitat is treeless open marshland, where black-crowns nest in herbaceous vegetation just inches above the water (Nelson 1876–1877, Murchison 1892). Nesting black-crowned night herons are sometimes associated with great blue heron-great egret colonies (or vice versa) in which situations the night herons' nests are always under the canopy and lower than the nests of the larger herons. Murchison (1893*a*) observed colonies especially in second-growth timber. The predominant species of nest tree for night herons at Pekin was green ash (Bjorklund 1975). Nests at Addison were also in ash trees and oaks (Eifrig 1913). Willows—presumably black willows (Jones 1937*a*, Cunningham 1941)—and silver maples are commonly used nest trees for black-crowns in the Mississippi Valley, but at East St. Louis, Galbreath (1961) noted the nest trees to be elms, hackberries, and pin oaks. Other tree species in which we have seen black-crown nests are catalpa and box elder. Frank Bellrose (un-

Black-Crowned Night Heron

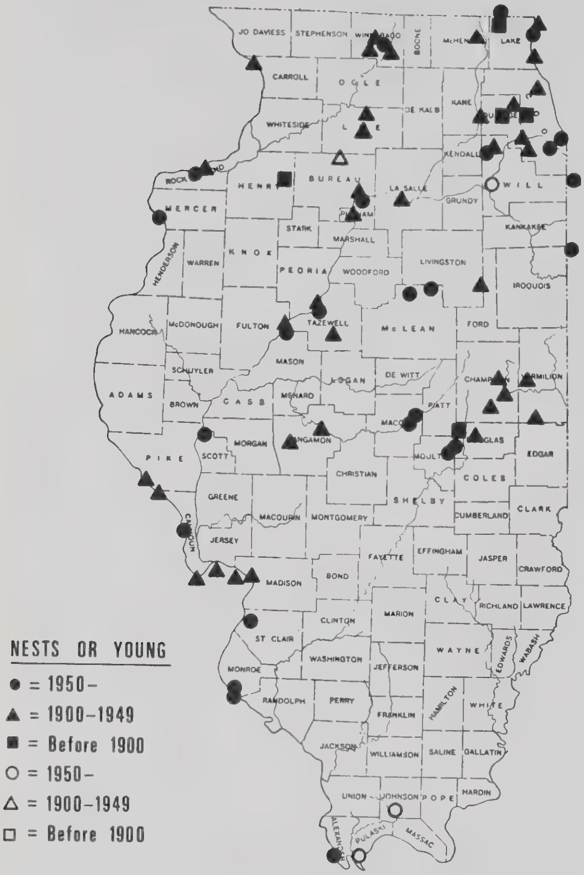

Fig. 38.—Distribution of nesting colonies and other breeding records of black-crowned night herons in Illinois.

published) found a colony near Delavan in a plantation of European larch *(Larix decidua).* Tree nests have been found as low as 1 m high, but generally they are 8–14 m high (Murchison 1893*a*, Eifrig 1919, Hammerslough & Bjorklund 1968). The open marsh nests were said to have been placed in wild rice (Nelson 1876–1877), but Kumlien & Hollister (1951) stated that the plant was actually *Phragmites.* Marsh colonies have not been reported in this century.

The nesting sites of this heron are so varied as to suggest that the nature of the nesting site *per se* is relatively unimportant compared with the nature of foraging areas. In its distribution the black-crown seems to be associated with marshland (Lobik 1952, Finley 1913), but its precise foraging ecology is unknown, probably in part because of its nocturnal activity pattern. McCarty (1928) reported that black-crowns tended to remain quiet between 8:00 am and 5:00 pm, but foraged along a small creek or the Embarras River when the creek dried up. Gross (1923) felt that the size of the Atwood colony was controlled by the available food supply. The colony, with a maximum of 12 nests, was about 10 miles from the contemporaneous Tuscola colony, and Gross believed that in dry years the birds were taxed to find enough food for their young and themselves. Coursen (1947) found the local colony at Orland to be highly variable from year to year, which complicates the interpretation of population trends. Black-crowns have in some cases exhibited strong tenacity to colony sites. The Chatsworth colony was believed to have been occupied for 50 years (Anonymous 1946), Tuscola for possibly 40 years (McCarty 1928), and Depue for at least 40 years. Hess (1910) noted that colonies in the Philo area appeared to fragment and scatter before they disappeared completely.

Night heron colonies are not visible from the air, and it is much more difficult to obtain an estimate of the state population than it is to obtain one for great blues or great egrets. As with other species of herons, no data exist on population densities of foraging night herons. On cross-country censuses in 1907–1909, Alfred Gross and Howard Ray encountered 15 black-crowns (at least 5 adults) in about 338 km of transects (about 1 per 22 km) in all habitats in northern and central Illinois. In 1957–1958 we encountered just 2 black-crowns in about 475 km of transects (1 per 237 km) in all habitats of those regions. Though the transects represent all habitats, the herons were seen mainly in small acreages of marsh, with pasture the second most common habitat. Pasture often contains marshy areas. The transects were all made in daytime and are not well designed to census foraging night herons, but the data do suggest a serious decline in the black-crowned night heron population in the past half century. Even earlier Widmann (1907) stated that the population had been greatly reduced. Other evidence of the decline is the disappearance of numerous colonies without apparent replacement (Fig. 38, Table 11). In fact, we personally know of only four extant Illinois colonies of any size—Waukegan, Plainfield, Clear Lake, and East St. Louis—all associated with areas that still have marshes nearby. Because black-crowned night heron colonies are easily concealed in small groves or marshes, we suspect that there are a number of other colonies still extant. It is important to locate the existing colonies and provide protection for both the nesting sites and the foraging areas. The extent and causes of the nesting population decline of this species are unknown, but the encroachment of humans on all habitats must certainly be a factor.

Nesting Cycle

Black-crowned night herons apparently go directly to the nesting colonies as they return from the winter range (see under spring migration above). At Tuscola, McCarty (1928) reported that the birds were relatively inactive during the first 3–4 days after arrival. Courtship and mating behavior in Illinois

Table 11.—Black-crowned night heron colonies in Illinois and adjacent areas.

Colony Site	County	Year	Number of Nests	Reference
Mississippi River Drainage				
Sabula, Iowa	Jackson	1943	2	Harlan (1943)
Sabula, Iowa	Jackson	1974	0	This paper
Andalusia	Rock Island	1948	P[a]	Hodges (1950)
Andalusia	Rock Island	1949	148	Hodges (1950)
Andalusia	Rock Island	1950	P	Hodges (1951)
Andalusia	Rock Island	1965	50 (+) [b]	Brown (1965), Petersen & Ward (1966)
Andalusia	Rock Island	1966	50	Petersen & Ward (1966)
Andalusia	Rock Island	1969?	P	Brown (1969)
New Boston	Mercer	1962	0	Brown (1962)
New Boston	Mercer	1965	P	Greer (1966)
New Boston	Mercer	1973–1977	0	
Atlas	Pike	1948	25	Musselman (unpublished)
Clarksville, Mo. (north)	Pike	1941	P	Jenkins (1942)
Clarksville, Mo. (north)	Pike	1942	60	Cunningham & Spotswood (1942)
Clarksville, Mo. (north)	Pike	1958–1959	P	W. H. Elder (unpublished)
Hamburg	Calhoun	1973	1	This paper
Hamburg	Calhoun	1974	0	This paper
Dardenne Lake, Mo.	St. Charles	1936	P	Jones (1936*b*)
Dardenne Lake, Mo.	St. Charles	1937	P	Jones (1937*c*)
Dardenne Lake, Mo.	St. Charles	1938	P	Jones (1940*b*)
Temps Clair Marsh, Mo.	St. Charles	1937	400	Jones (1937*a*)
Temps Clair Marsh, Mo.	St. Charles	1938	100 (−)	Jones (1938*a*)
Alton	?	1941	75	Cunningham (1941)
St. Louis, Mo.	St. Louis	1945	P	Cunningham (1945)
Grand Marais (East St. Louis)	St. Clair	1955	P	Comfort (1955*b*)
Grand Marais (East St. Louis)	St. Clair	1958–1959	P	Comfort (1958*a*, 1959)
Grand Marais (East St. Louis)	St. Clair	1961	250	Galbreath (1961)
Grand Marais (East St. Louis)	St. Clair	1962	100	Anderson (1962*b*)
Grand Marais (East St. Louis)	St. Clair	1963	150	Anderson (1963*b*)
Grand Marais (East St. Louis)	St. Clair	1964	P	Anderson (1964*a*)
E. St. Louis (Comment Sanctuary)	St. Clair	1964–1976	P	Wrischnik (1973, 1975–1976), Kleen (1974–1975, 1976–1977)
Fults Marsh	Monroe	1964?	"many"	Anderson (1964*c*)
Fults Island	Monroe	1971?	P	Fleig (1971)
Fults	Monroe	1974	95	This paper
Fults	Monroe	1975	15	This paper
Fults	Monroe	1976	0	This paper
Commerce, Mo.	Scott	1975	200	This paper
Illinois River				
Starved Rock	La Salle	1944	P	Ries & Werner (1946)
Depue	Bureau	1937	8	Bartel (1937)
Depue	Bureau	1973	51	This paper
Hennepin	Putnam	Prior to 1907	P	Bellrose (1939*b*)
Big Lake (Duck Island)	Fulton	1938	P	Bellrose (1939*b*)
Pekin	Tazewell	1962–1972	6–355	See Bjorklund (1975) for complete record
Pekin	Tazewell	1973	0	Bjorklund (1975)
Clear Lake	Mason-Tazewell	1973	109	Bjorklund (unpublished)
Clear Lake	Mason-Tazewell	1977	140	Bjorklund (unpublished)
Naples	Scott	1974	10 (+)	J. Funk (unpublished)
Areas Other Than Mississippi and Illinois Rivers				
Rockford (northwest)	Winnebago	1921?	P	Riis (1921)
Winnebago	Winnebago	1938–1940	P	Bartel (1942)
Winnebago	Winnebago	1955	0	Anonymous (1955)
Rockford area	Winnebago	1947	P	DuMont (1947*b*)
Rockford area	Winnebago	1961	P	Johnson (1961)
Franklin Grove	Lee	1925	P	Blocher (1926)
Amboy	Lee	1933–1934	P	Blocher (1937)
Annawan area?	Henry	1892?	Many	Murchison (1892)
Antioch (north in adjacent Wisconsin)	Kenosha	1954–1956	P	Williams (1957)
McHenry (west)	McHenry	1931–1932	P	Anonymous (1933)
McHenry (west)	McHenry	1934	P	Sanborn (1934*b*)

(Table 11 continued on next page.)

Table 11.—Continued

Colony Site	County	Year	Number of Nests	Reference
Grass Lake	Lake	1876	50	Nelson (1876–1877)
Beach	Lake	Before 1914	P	Sanborn & Goelitz (1915)
Lake County (location?)	Lake	1921	250	Ford et al. (1934)
Waukegan	Lake	1975	1	Kleen (1975–1976)
Waukegan	Lake	1976	26	Kleen (1976*c*)
Lake Forest	Lake	1941	2	Smith (1941)
Skokie	Cook	1940?	"large colony"	Langdon (1940)
Skokie	Cook	1947	125	DuMont (1947*b*)
Palos Hills (Sag)	Cook	1913?	Many	Finley (1913)
Orland	Cook	1921	250	Sanborn (1921)
Orland	Cook	1932	P	Strong (1932)
Orland	Cook	1921	200	Coursen (1947)
Orland	Cook	1945	60	Coursen (1947)
Lake Calumet	Cook	1951–1952	P	Bartel (1952), Lobik (1952)
Lake Calumet	Cook	1961	100	P. Norton (unpublished)
Lake Calumet	Cook	1975	0	Kleen (1975*a*)
Blue Island	Cook	Before 1959	400?	Mumford (1959)
Blue Island	Cook	1959	0	Mumford (1959)
Elmhurst (Addison?)	Du Page	1895	P	Farwell (1919)
Addison (Two sites)	Du Page	1911–1919?	P	Eifrig (1911, 1913, 1915*b*, 1919)
Glen Ellyn	Du Page	1891	P	Gault (unpublished)
Geneva	Kane	1927	P	Gault (unpublished)
Plainfield area	Will	1942	P	Bartel (1942)
Plainfield area	Will	1949	800	Ford (1956)
Plainfield area (Lake Renwick)	Will	1971	150	This paper
Plainfield area (Lake Renwick)	Will	1973	146	This paper
Plainfield area (Lake Renwick)	Will	1977	41	J. W. Olson (unpublished)
St. John, Ind.	Lake	1950–1956?	P	Ford (1956)
Willow Slough, Ind.	Newton	1953	P	Ginn (1954)
Willow Slough, Ind.	Newton	1959	0	Mumford (unpublished)
Chatsworth	Livingston	1946?	P (50 years)	Anonymous (1946)
Chenoa	McLean	1958–1959	P	S. Schenck (unpublished)
Gridley (south)	McLean	1964	P	D. Birkenholz (unpublished)
Delavan (north)	Tazewell	About 1938	P	Bellrose (unpublished)
Berlin	Sangamon	1941	1	Robertson (1941*a*)
Lake Springfield	Sangamon	1949?	P	Eifert (1949)
Lake Decatur	Macon	1959	5	C. T. Nearing (unpublished), Thompson (1960)
Decatur (northeast)	Macon	1952–1958	20	F. Irwin (unpublished), R. Sandburg (unpublished)
Arthur	Moultrie	1972–1975	7	F. Irwin (unpublished), C. T. Nearing (unpublished)
Cadwell	Moultrie	1966	11	This paper
Atwood	Douglas	1899–1909	12 (max.)	Gross (1923)
Tuscola	Douglas	About 1890–1928	P	McCarty (1928)
Tuscola	Douglas	1935	P	Black (1935)
Rantoul (north)	Champaign	Before 1967	P	J. and R. Meece (unpublished)
Philo (SW, Embarras River)	Champaign	1901	38	Hess (1902, 1910)
Philo (SW, Embarras River)	Champaign	1902	38 (+)	Hess (1902, 1910)
Philo (SW, Embarras River)	Champaign	1901–1909	P	Black (1935)
Salt Fork (location?)	Champaign	1909	P	Hess (1910), Black (1935)
Sidney	Champaign	1910	P	Black (1935)
Urbana (east)	Champaign	1949	1	Miller (1955)
Sidell	Vermilion	1911?	P	Anonymous (1911)
Fithian	Vermilion	1936	P	Bellrose (unpublished)

[a] Nests present but not counted.

[b] The plus or minus sign indicates an approximate number larger (+) or smaller (—) than that shown.

have not been described, nor have the vocalizations. The call most often heard is the loud, abrupt note, "quok," often heard singly; however, sometimes several notes run together in a string.

The age composition is unknown for any Illinois population. Gross (1923) saw some yearling birds nesting in a colony in Massachusetts. Whether first-year birds, in general, breed is not known.

Night herons reuse old nests, which are refurbished with fresh material (McCarty 1928, Gross 1923), and both members of the pair participate in the building. Tree nests have not been described in Illinois. Marsh nests were generally built of green rushes and stalks of marsh grass, but sometimes of sticks carried some distance (Murchison 1892 and 1893*a*). The marsh vegetation, which grew in water 61–91 cm deep, was formed into a platform 5–15 cm in depth, often so flat that eggs rolled off. The nests had a pentagonal or hexagonal shape, 30–38 cm in diameter (Nelson 1876–1877). In New England tree nests usually were built in 2–5 days (Gross 1923). Some of the nests are frail and flat, and Gross saw both eggs and young dumped out by the wind.

The eggs, which are greenish-blue or pale blue when fresh, are laid on alternate days, and incubation begins with the first egg (Palmer 1962, Gross 1923). Mainly from hatching and fledging dates, we have estimated the laying season to extend from at least 24 April to 18 June in central and northern Illinois (Fig. 37). There are very few data for central Illinois, and none for the south, on any phase of the life cycle. Most of the egg sets (usually fresh) that we have seen in museums were taken in May, and Harris (1936) refers to a fresh set of five eggs taken on 12 May in Cook County. Eifrig (1915*b*) found night herons still building nests and with no eggs laid on 1 May at Addison. The pairs of a colony may not necessarily be synchronized in laying. Murchison (1893*a*) found eggs nearly ready to hatch in some nests on 27 May in a Winnebago County colony, where some birds were still building nests. In Lake County, Nelson (1876–1877) found both fresh eggs and young as old as 10 days on a day in June. These differences may have stemmed from an earlier loss of some of the nests in the colonies, as we have noticed that most nestlings in a colony tend to be of similar age (Fig. 41), indicating synchronization of laying. Some variation in the ages of nestlings is to be expected because incubation begins with the first egg.

Murchison (1893*a*) found considerable variation in clutch size among colonies of black-crowns. In Lake County he saw clutches with 3–5 eggs, averaging 4, but in Winnebago County sets were usually 4–5 eggs with some of 6. At a marsh colony in Henry County, following an egg-stealing raid by the local human populace, Murchison (1892) saw that most nests had 3 eggs and none more than 4. Fifteen clutches of black-crown eggs in the Field Museum, taken 1893–1900, were mainly of 4 eggs (eight sets), with three sets of 3 eggs, and two of 5 eggs. There were two sets of 7 eggs, an uncommonly large clutch in Illinois. There are no recent data on clutch size. Hatching rates are unknown.

Gross (1923) found the incubation period to be 24–26 days, and he shows the development of young to 44 days of age, when they are essentially full grown. Palmer (1962) noted the age of first flight for black-crowns to be 6 weeks. At East St. Louis young still in the nest have been seen as late as 13 September (Fawks 1970*a*), but this must be exceptionally late. More typically we would expect all of these birds to be fledged before the end of August. There is a great need for data on nesting success and productivity. The only Illinois information on the subject is the observation by Neal (*in* Kleen 1976*c*) that 26 nests at Waukegan produced 86 young (3.3 young per nest). The causes of nest failures are unknown.

Fall Migration

As do other Illinois herons, black-crowns move northward after the nesting season. What percentage of the population moves north is unknown, but apparently many do. About one-third of the recoveries of black-crowns (of all ages) banded in Illinois were retrieved in Wisconsin, i.e., north of the colonies banded (Bartel 1976). These northward flights begin in August very soon after the nesting actvities finish. Illinois birds have been recovered in Wisconsin as early as 21 August and as late as 1 November (Bar-

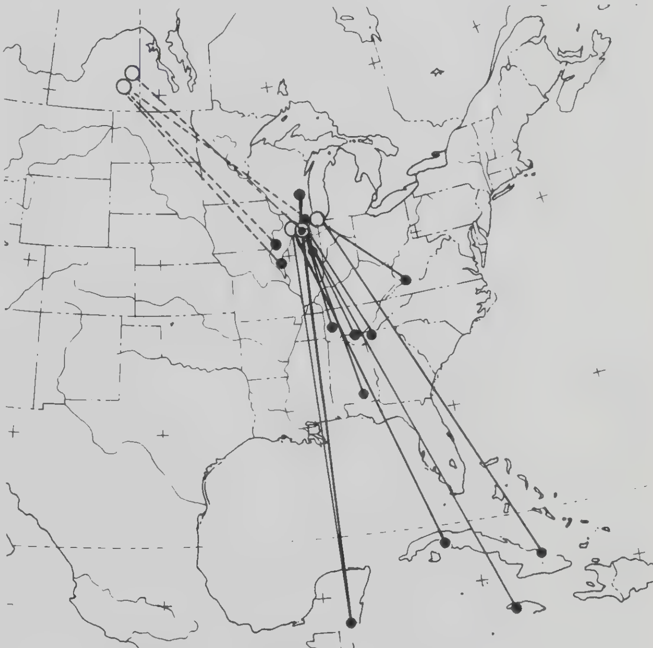

Fig. 39.—Distribution of recoveries (solid dots) of black-crowned night herons (1) banded in Saskatchewan as nestlings and recovered in Illinois, and (2) banded in Illinois as nestlings. Circles show locations of banding stations.

tel 1976). How soon the southward flights begin is not known. Night herons banded in Canada have been recovered in Illinois in October (Houston 1967, Fig. 39), and an Illinois-banded young night heron was recovered in British Honduras in October (Bartel 1976). There is no way to tell when these southward flights were initiated.

We have heard night herons calling over east-central Illinois farmland, at sites with no local colony, on about one-third of the nights between 21 August and 28 October. The calls were heard during all hours of the night, especially between 8:00 and 11:00 pm CST. There was much more calling in September and early October than in August or after 10 October, and we suspect that the September and early October calls were those of migrating birds.

The counts of night herons (Fig. 37) fall off sharply in late September and early October, a change that probably represents a general exodus of birds from the north, i.e., both local birds and those from north of Illinois. Though most of the population is south of Illinois by the end of October, there are

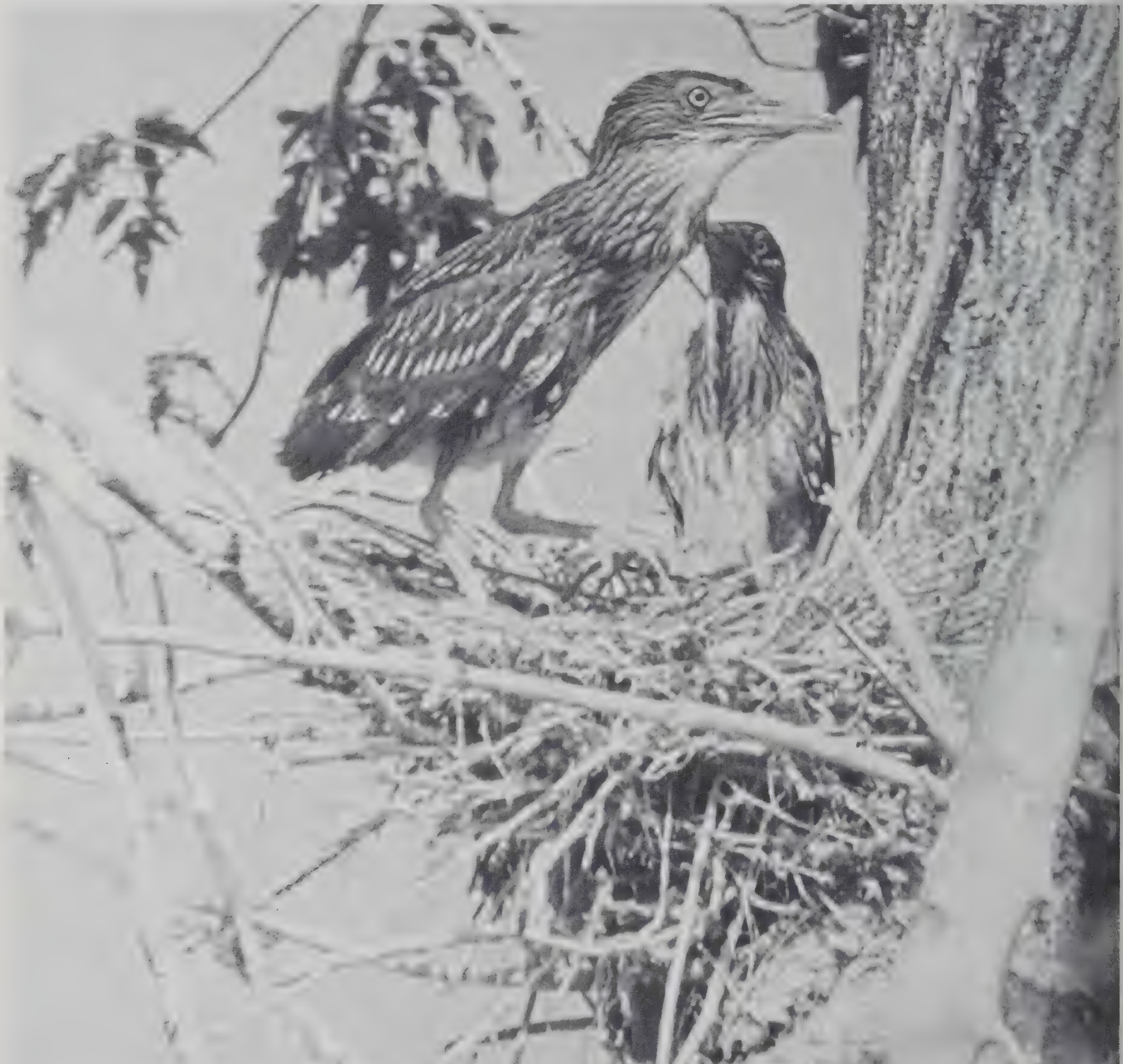

Fig. 40.—Young black-crowned night herons in their nest. The streaked appearance is retained for several months and closely resembles that of the young yellow-crowned night heron (not shown).

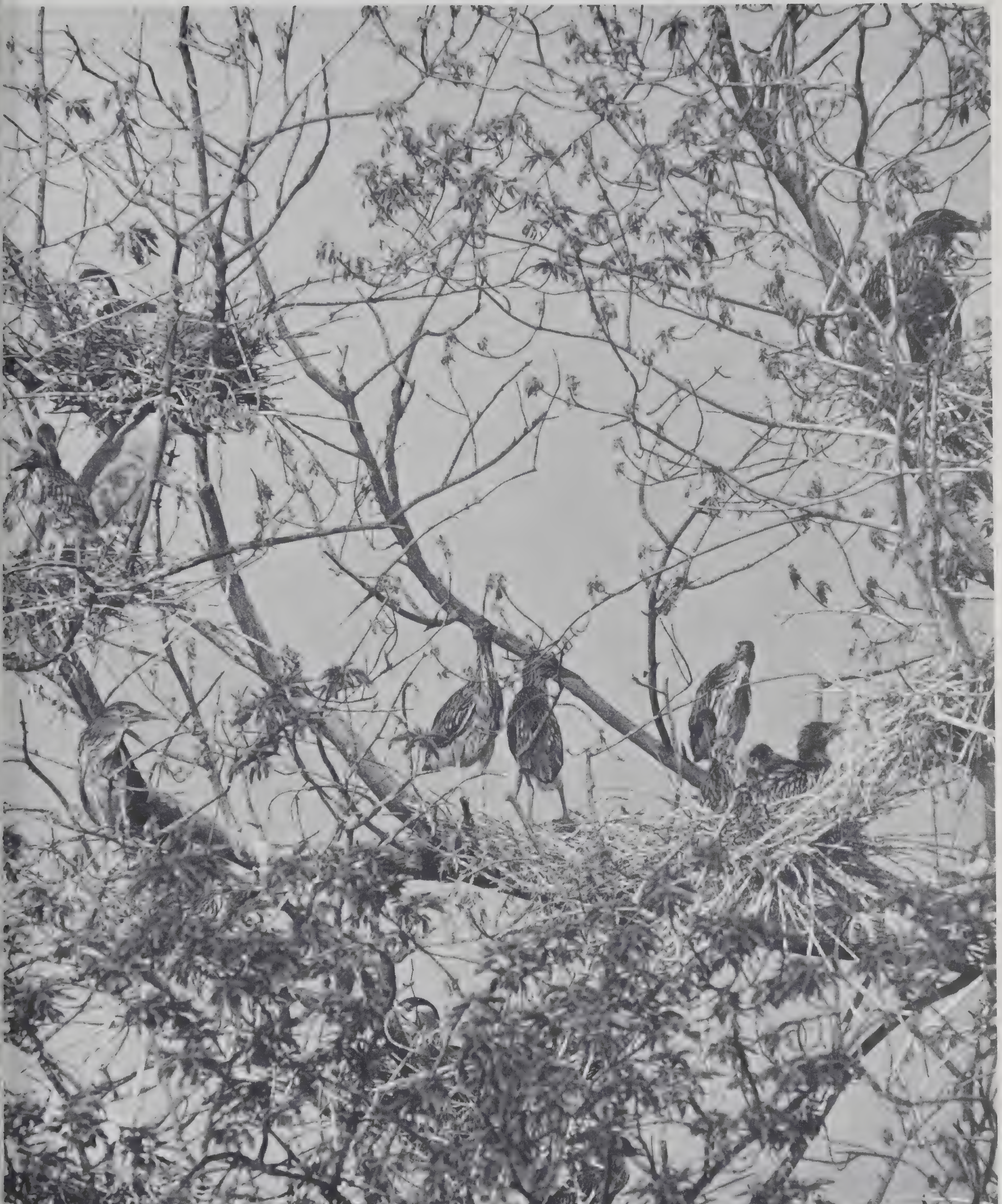

Fig. 41.—Part of the nesting colony near Plainfield, showing both adult and juvenile black-crowns at several nests.

enough November and December records even in northern Illinois to suggest that a few black-crowns tend to linger, perhaps regularly (Eifrig 1917, Boulton & Pitelka 1939, Boulton & Beecher 1940, Fawks 1966*a* and 1970*a*).

Unfortunately, no observers have kept track of age ratios of night herons on any systematic basis, but such data may be useful as a measure of productivity. The distinctive imature plumage (Fig. 40 and 41) is retained for more than a year and is an easily recognizable age indicator (Gross 1923). The counts of black-crowns (from all sources) in northern Illinois show a ratio of 1.0 bird seen in spring (March–May) to 2.9 in late summer and early fall (August–October). The central Illinois counts are too fragmentary to consider.

Winter Records

The cold-hardiness of black-crowned night herons is attested to by the fact that some have apparently survived northern Illinois winters (Blake 1948*b*, Nolan 1953*a*, Kleen & Bush 1971*a* and 1972*b*). Shirley Schenck (unpublished) observed black-crowns at their colony site in Chenoa in January 1960, and there are numerous scattered winter records (Fig. 42). However, the survival rate for the species in winter in Illinois is not known. Ridgway (1881) considered the black-crown to be a winter sojourner in southern Illinois, but there are very few specific records for the south. Link (1940) and Jones (1940*a*) reported on a specimen that did not survive the winter at Pere Marquette Park. The general absence of February records of black-crowns in any part of the state may imply poor winter survival or just a paucity of observers at that season. Birds that wintered in the Beach area in 1921 (Eifrig 1921) and the Chicago area in 1971 and 1972 (Kleen & Bush 1972*b*) were identified as immatures, as was a February specimen in the Rock Island area (Mumford 1960*b*), but most of the winter birds have not been aged. The majority of winter records of black-crowns are recent (Fig. 42), possibly reflecting only the increased interest in birds in recent years. The absence of records generally from southern and western Illinois is perhaps related to the scarcity of observers in those areas.

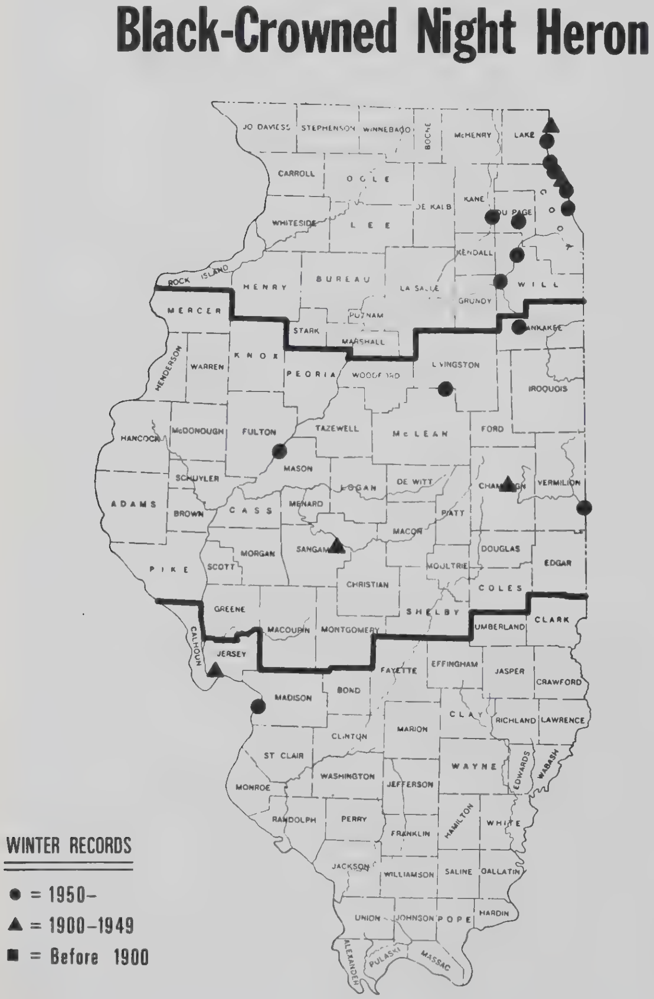

Fig. 42.—Distribution of winter (15 December–1 February) records of black-crowned night herons in Illinois.

Food

Food specimens regurgitated by young black-crowned night herons at three Illinois colonies—Plainfield, Depue, and Fults—showed much the same dominant prey species as those used by great blues and great egrets in the state. Of 128 identifiable items recovered, 102 (79.7 percent) were gizzard shad, 16 (12.5 percent) were carp, and 7 (5.5 percent) were sunfish (mainly green, one orangespotted), plus 1 (0.8 percent) longnose gar, 1 black crappie, and 1 crayfish. Food items ranged from 2 to 18 cm in length. Carp were larger, on average (12 cm), than the shad (7 cm) or sunfish (8 cm). McCarty (1928) also recorded the food at Tuscola as small fish and crayfish, but at Atwood the chief foods were frogs and crayfish (Gross 1923). In Cook County, Sanborn (1934*b*) found black-crowns feeding on painted turtles.

The foraging techniques of black-crowns have not been described. They apparently are capable swimmers. Pitelka (1937) observed two adults floating in open deep water in the fashion of gulls, with wing tips and tail held above the water, but there is no evidence that the birds were foraging in this way.

Longevity and Mortality

Bartel (1976) banded 1,144 nestling black-crowned night herons at colonies—Winnebago, Plainfield, and Lake Calumet—in northern Illinois between 1937 and 1952. He obtained recovery data on 25 (Bartel 1958 and 1976). An additional recovery was published by Cooke (1938). We considered all recoveries to represent losses to the population, and plotted the losses against age (Fig. 43). The oldest bird (recovered as a skeleton) probably had survived for over 14 years, and the average age of all birds recovered was about 2 years and 11 months. Young birds had poor survival, with about 61 percent lost in the first year. As with the great blue, a high percentage (42) of the birds were shot (admittedly so) and the other birds designated "found dead" may also have been shot. Most of the birds were killed in late summer and fall, the highest percentage (16) in November (Fig. 43), a month when many hunters are active, and much of the mortality must be attributed to (illegal) hunter vandals. After the less wary birds are eliminated, survival improves. In a much larger sample of recoveries representing North America, Hickey (1952) found that 52 percent of the young black-crowned night herons were lost in the first 4 months. Adult (birds over 1 year) mortality, calculated by the method of Lack (1949), was about 27 percent per year (excluding the four oldest birds) for the small Illinois sample and about 30 percent per year based on the North American recoveries (Hickey 1952).

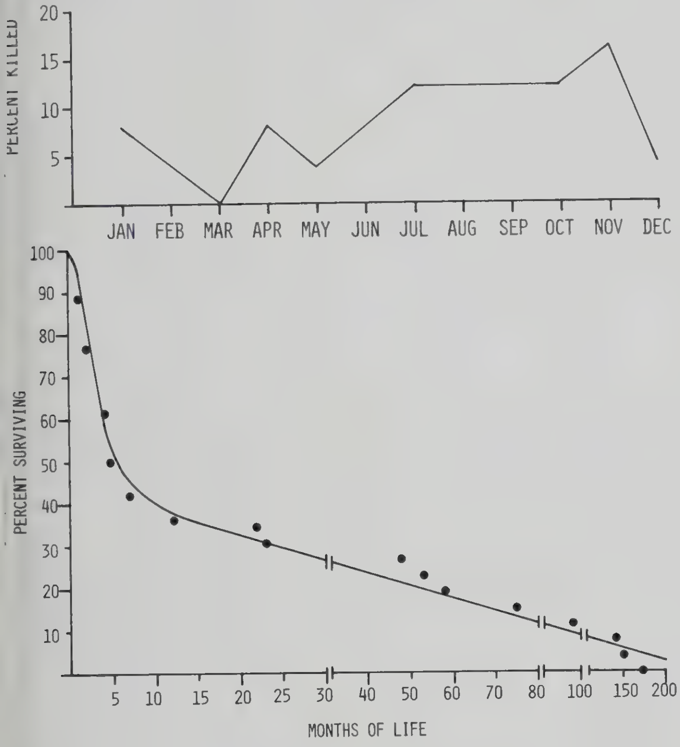

Fig. 43.—(Top) Distribution, by month, of banded black-crowned night herons killed, many by hunter vandals. (Bottom) Survival (or mortality rate) of black-crowned night herons banded as nestlings in northern Illinois. A dot may represent more than one bird.

YELLOW-CROWNED NIGHT HERON
(Nyctanassa violacea)

(Fig. 44 and 45)

Spring Migration

Yellow-crowned night herons are not usually detected in Illinois until April, but there is at least one March (29th) record for southern Illinois (R. D. Palmer unpublished, Kleen 1975*c*). There are early April records for southern Illinois (George 1968) and even for the north (DuMont 1947*a*, Fawks 1967*a*). However, yellow-crowns are more often first detected in the state in mid- or late April, and peak numbers are seen in May and early June (Fig. 46). The migration has never been observed, and the counts may relate more to the timing of human activity than to that of the birds. Our peak counts of foraging birds seen per day were 10 and 14 birds, seen in May in southern Illinois. Much more commonly we saw only 1–3 birds per day.

Distribution

The yellow-crowned night heron is a species of the eastern United States and Central and South America (Fig. 45). In Illinois it has a spotty distribution the length of the state (Fig. 47). Most of the records are recent, and undoubtedly additional nesting localities will be discovered. The species nested at least as far north as Depue in the 1930's (Bellrose 1938) and as far north as Cook County in 1949 (McMillen 1964). It is uncertain whether the increased frequency of records in the north (Nolan 1954*a*) reflects a population change or only more and better observers. The yellow-crown is known from Indian middens in Randolph County, dating back perhaps to 8000 BC (Parmalee 1959). Black-crowned night herons were not detected in the deposit. One record not shown in Fig. 47, for lack of specific locality data, is a record mentioned by Nolan (1954*b*) for an area south of Chicago.

Nesting Habitats and Populations

Though nesting yellow-crowned night herons are sometimes associated with colonies of other herons, including black-crowns (Bellrose 1938, Nolan 1954*b* and 1955*b*, Brown 1962), they also nest solitarily or in small colonies of yellow-crowns only (Nelson 1876, Boughner 1960, Haertel 1963). Ridgway (1882) referred to a colony near Vincennes of "perhaps a hundred pairs," but no other colony on record for this region even remotely approaches that size. Nesting is usually in lowland woods, including second growth as well as mature stands (Ridgway 1882, Mayfield 1950*b*). Ridgway's (1882) description of Monteur's Pond near Vincennes may be an apt description of yellow-crown nesting habitat. The "pond" was a swamp about 14 km by 2 km with less than half its area in open water no more than 1.2 m deep. The rest of the area was in trees, chiefly willows 15–19 m tall, and larger ashes, red maple, and swamp cottonwood, with some oaks ("swamp, white, and water oaks"), sweet gums, and an occasional catalpa.

Of the five nest trees identified for yellow-crowns in Illinois, three were oaks, one an elm, and one a river birch (Nelson 1876, Haertel 1963). Ridgway

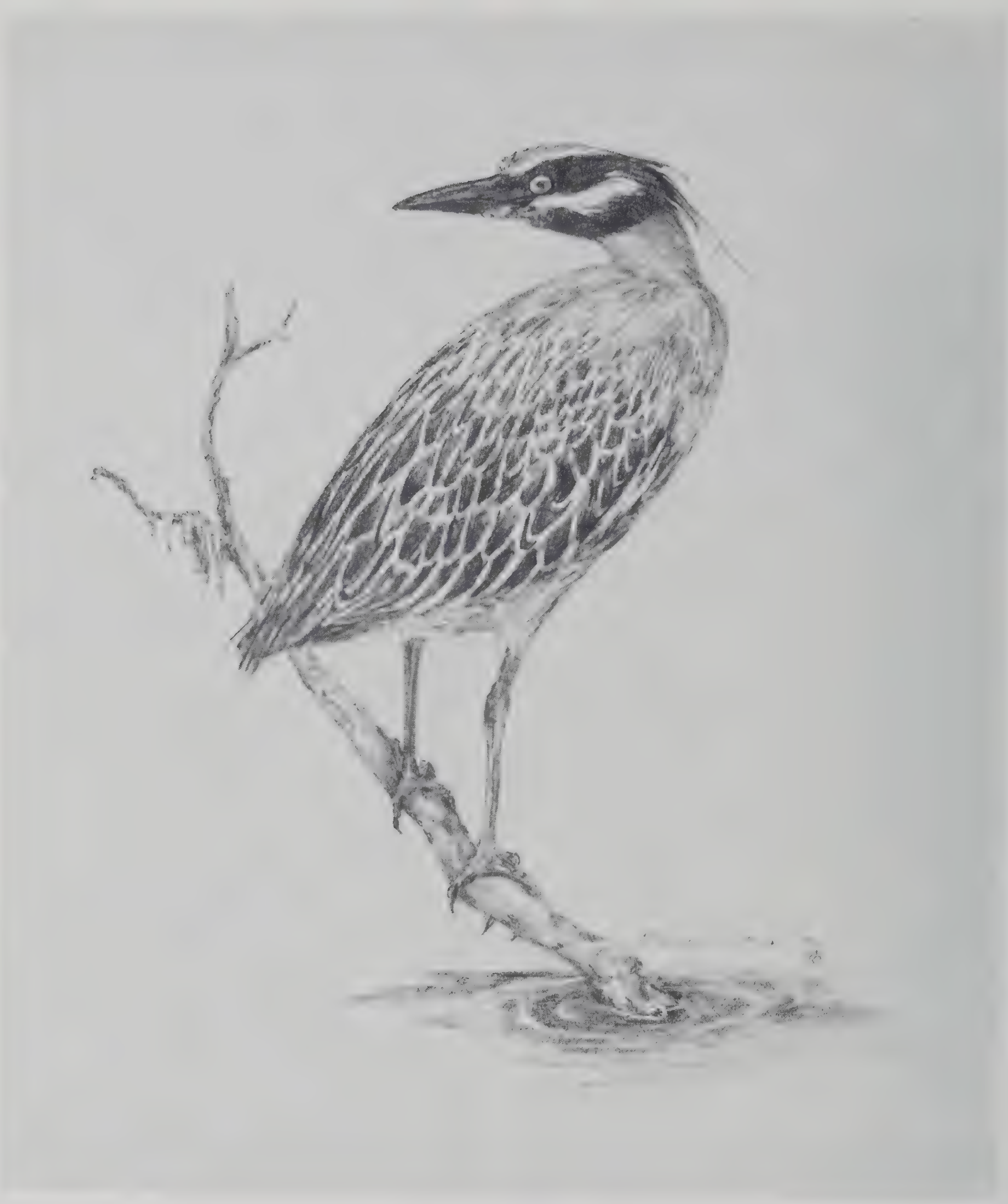

Fig. 44.—Adult yellow-crowned night heron, from a drawing by Beverly Sanderson. Similar in size (about 50 cm tall) to the black-crowned night heron, this species, with its bluish gray body, is distinctive. The immature of this species is similar to the immature black-crown (Fig. 40).

(1882) referred to nests near Vincennes, Indiana, that were "among" ash and sweet gum trees. Later (Ridgway 1895) stated that the nests were "in" sweet gum and oak trees and that the nests were placed high. Six Illinois nests had a height range of 11–18 m (average 14 m) (Nelson 1876, Gylleck 1960, Haertel 1963, and I. Wasson unpublished).

The vegetation and other characteristics of the nesting habitat have not been analyzed quantitatively, nor has the foraging habitat been defined. We have seen yellow-crowned night herons foraging in swamps and lagoons and even in plowed fields.

The cross-country censuses did not intercept any yellow-crowns either in 1907–1909 or 1957–1958, probably only because of insufficient sampling of bottomland forest. Our more recent (1973–1977) strip censuses of 824 ha of mature bottomland forest in southern Illinois showed an average population of 0.54 yellow-crown per 40.5 ha, with annual variations (for all tracts) of from 0 to 1.2 per 40.5 ha. The highest population recorded was at Oakwood Bottoms (Jackson County), a consistently good area for yellow-crowns, where the population was 7.8 birds per 40.5 ha in 1975–1976 (42 ha censused).

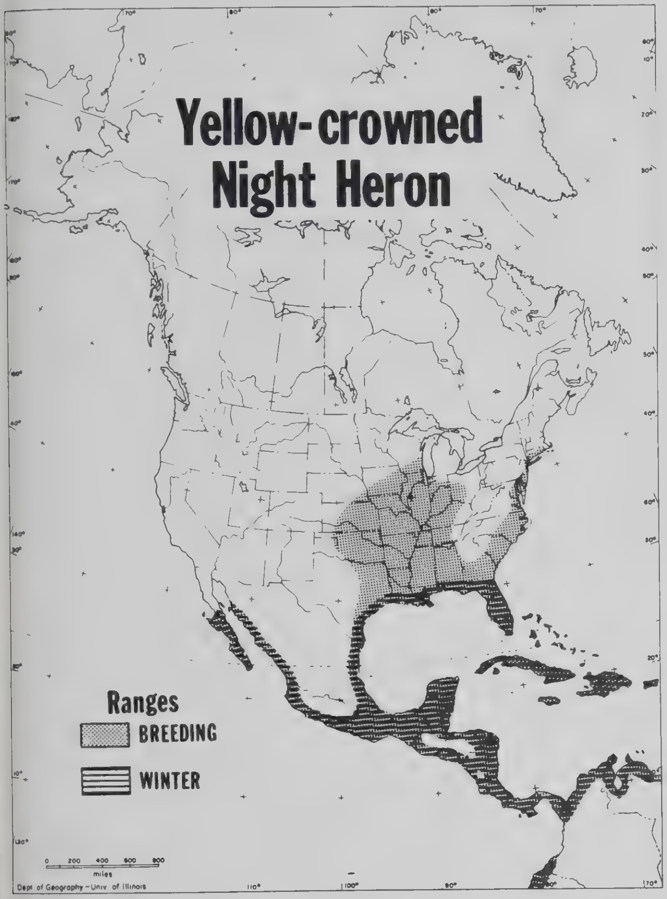
Yellow-crowned Night Heron
Ranges
BREEDING
WINTER
0 200 400 600 800
miles
Dept. of Geography - Univ. of Illinois

Fig. 45.—General distribution of the yellow-crowned night heron.

The increasing frequency with which this species has been reported in recent years (Jones 1940*c*, Nolan 1954*a*, Anderson 1974*b*) may only represent increased interest by more and better observers. However, the total absence of yellow-crown records from the notes of such keen observers as Nelson (1876–1877) and Gault over such a long span of years (1875–1927) tends to support the view that there has been a population increase, at least in the north. Even so, the yellow-crown's population bears careful monitoring, both because the total Illinois population is relatively small (less than 1,000 birds), and because it nests in a threatened habitat.

Nesting Cycle

Very little has been recorded on the nesting of the yellow-crowned night heron in Illinois or anywhere else (Palmer 1962), and there are no quantitative data on any phase of the cycle for any population. The courtship and nuptial behavior have apparently never been reported. The call notes are reported to be similar to those of the black-crown but higher pitched (Palmer 1962). We have never heard one utter a sound.

Nest construction was under way at New Boston by 28 April (Brown 1962), and a nest at Evanston

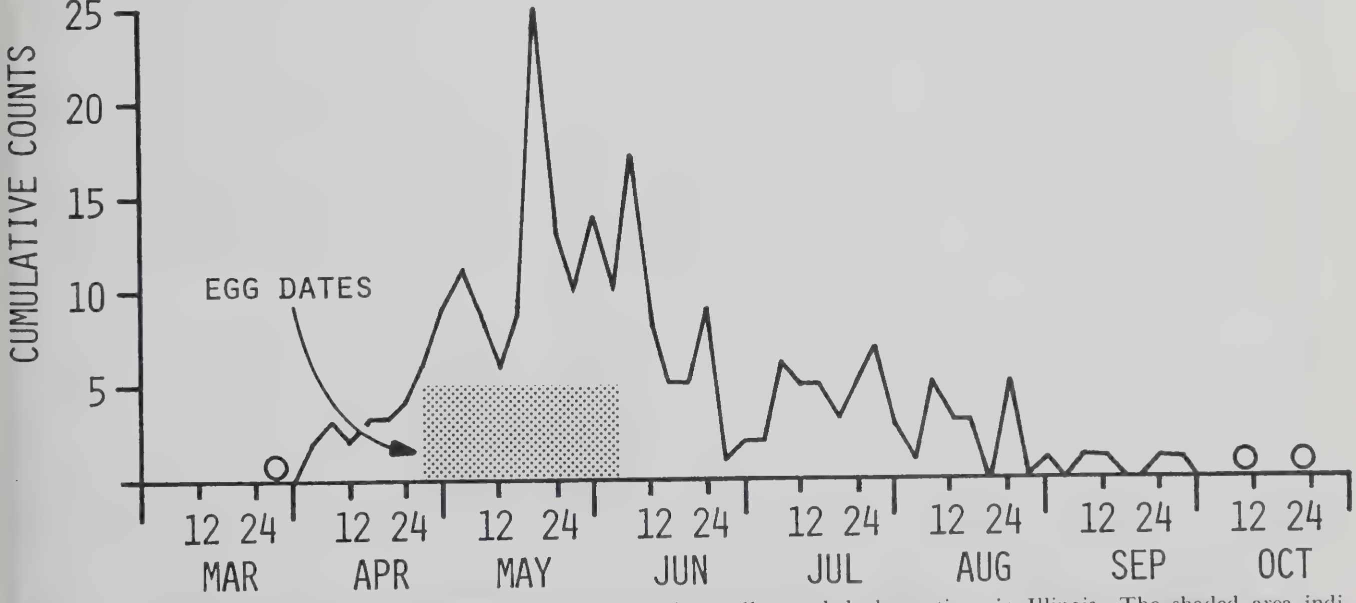

Fig. 46.—Cumulative counts of yellow-crowned night herons from all recorded observations in Illinois. The shaded area indicates the span of dates in which eggs have been found in yellow-crown nests (not the same as the egg-laying season). Circles indicate the earliest and latest records in the state.

Yellow-Crowned Night Heron

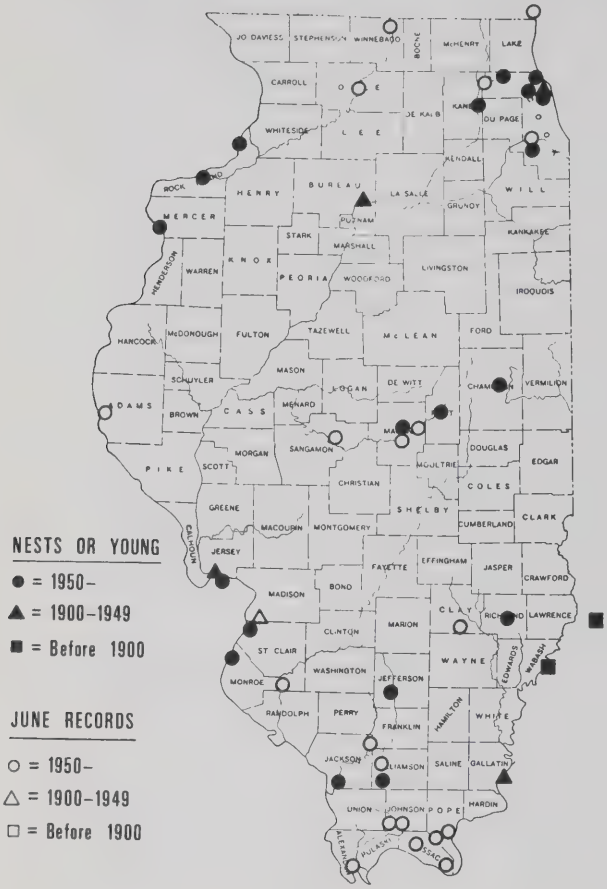

Fig. 47.—Distribution of breeding records of yellow-crowned night herons in Illinois.

was completed by 10 May (Nolan 1953*b*). The nest, which superficially at least, resembles tree nests of the black-crown, is often saddled on a branch well out from the trunk (Nelson 1876, Ridgway 1895), but is sometimes adjacent to the trunk (Haertel 1963). The eggs of the yellow-crown are very similar in color (pale bluish green), size, and shape to those of the black-crowned night heron (Reed 1965). The beginning of the egg-laying season is indicated by a female specimen with an egg in her oviduct on 27 April, when she was collected from her nest near Vincennes by Ridgway (1882). Eggs have been reported in active Illinois nests from 6 May to 4 June (Nelson 1876, Bellrose 1938), and we would expect the season to extend much later. The incubation period at an Indiana nest was estimated to be 24–25 days (Weeks 1976).

Excellent illustrations by McVaugh (1972 and 1975), showing the development of young night herons in North Carolina and Florida, suggest that the rate of development is similar in yellow-crowned and black-crowned night herons. The young are largely grown in 35 days, though the age of first flight of the yellow-crown is apparently unknown. Data on the number of eggs laid are almost nonexistent. Two nests at Depue each produced four young that apparently lived to or near to the age of fledging (Bellrose 1938), and a nest near Elgin (Gylleck 1960) and one observed by us at Rend Lake each had three young though it is not known whether they fledged.

Fall Migration

There are no data on the postbreeding behavior of yellow-crowns, the timing of the molt, or the fall migration. The migration has never been seen, and the available counts give no indication of an increase in numbers in late summer or fall, as might be expected (Fig. 46). Few are seen after August, but there are at least two October records, the latest 22 October (Fawks 1968 and 1971*c*, Fig. 46).

The yellow-crown is another species in which a distinctive immature plumage could, with systematic monthly counts, be used to determine age ratios as a possible measure of productivity, but the problem of finding a significant sample of yellow-crowns in late summer and fall must first be solved.

Food

The food of the yellow-crowned night heron differs strikingly from that of the black-crown, particularly in the absence of fish from the yellow-crown's diet. Ridgway (1895) stated that the yellow-crown's principal food was crayfish and frogs though he gave no specific identifications. Quantitative data are needed on the subject.

LEAST BITTERN *(Ixobrychus exilis)*

(Fig. 48 and 49)

Spring Migration

As in the case of the American bittern, the secretive nature and specialized habitat of the least bittern make it difficult to obtain a quantitative record of its migration or any phase of its life cycle, and we have plotted all the records available to us to show when most of these birds have been seen (Fig. 50). Least bitterns have not been seen in Illinois before 7 April (Kleen 1974*c*), and are not seen with any regularity until late April or May (Fig. 50). More have been seen in May after the 8th than in any other month, but this probably has more to do with the timing of field work by human observers than with the population of the least bittern.

The migration is believed to be nocturnal but has never been observed (see under Fall Migration).

Distribution

The least bittern is spottily but widely distributed in the United States and Central and South America

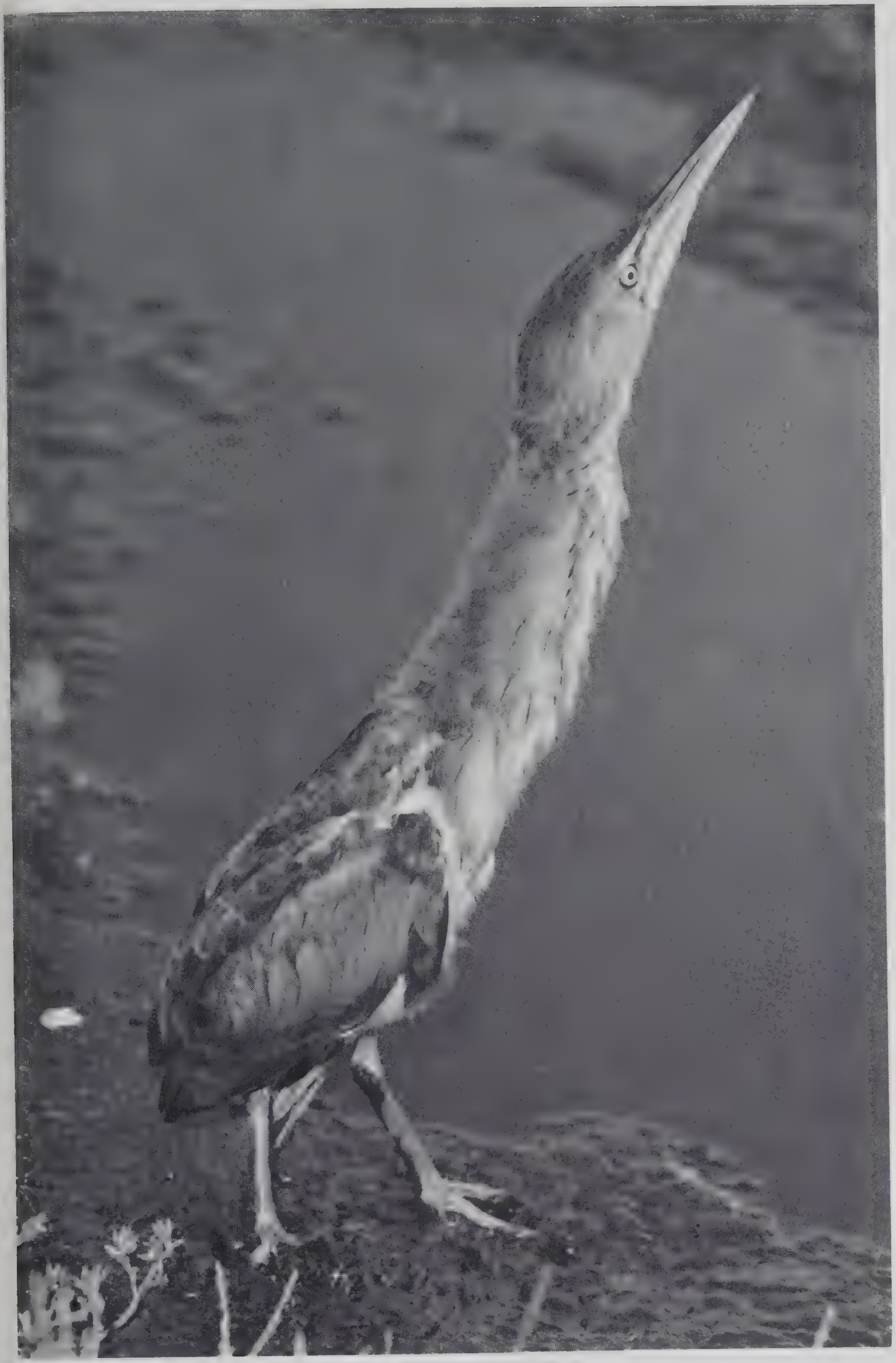

Fig. 48.—Immature least bittern. The smallest (about 25–30 cm tall) Illinois heron, the least bittern is rarely, if ever, seen in the open (this specimen was an injured captive). The adult has a dark back (blackish in the male, brownish in the female), with large patches of buff on the wings.

(Fig. 49). In Illinois least bitterns have been found nesting mainly in the north, sometimes in the south, but rarely in central Illinois (Fig. 51). We would have suspected that this distribution only represented lack of coverage, but such experienced observers as Isaac Hess (Champaign County) and T. E. Musselman (Adams County) did not report nests from their areas. Because much of the state's marshland has been destroyed, there may be few suitable nesting areas left for the least bittern, but once they are adequately explored, a number of counties in all parts of the state may prove to have small nesting populations.

Least bitterns have been less frequently detected in Indian middens than have the larger American bitterns, but two records of leasts date from about 1800 to possibly 8000 BC (Parmalee 1959 and 1964).

Nesting Habitats and Populations

Least bitterns apparently nest only in marshes. In Lake County, Beecher (1937 and 1942) found dense populations in both lake and pond growths of cattails (12 nests in 4.2 ha of lake and 4 nests in 2.3 ha of pond growth) and *Carex lacustris* (lake, 4 nests in 2.2 ha; pond, 4 nests in 0.6 ha), but only one nest

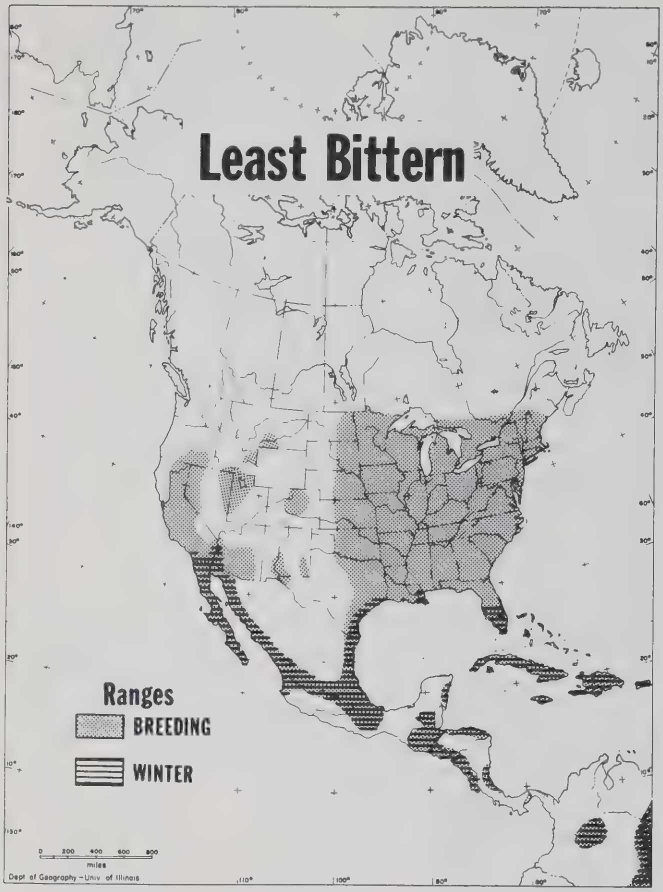

Fig. 49.—General distribution of the least bittern.

in 16.2 ha of mixed *Carex* species. The only habitat in which we encountered the least bittern on cross-country censuses was cattail marsh in Lake County (0 in 1957, 10 per 40.5 ha in 1958). Also in the central and southern regions nests were found in cattails (Lux 1892, Butler 1897, Bennett 1953). Murchison (1893*b*) observed that least bitterns always nest over water—usually 25–46 cm deep—and he attributed the high population in Henry County in 1892 to adequate water. Coincidentally, the population was also high in that year at Calumet (Larsen 1893). In Lake County, Goelitz (1915) found nests over water about 1 m in depth. Murchison (1893*b*) pointed out that a difference between American and least bittern habitat is that American bitterns nest only around the edge of a marsh, whereas least bitterns nest throughout the marsh. Least bittern nests are placed in the densest stands of reeds (Barnes 1890*a*, Woodruff 1907, Bailey 1928). Territory has not been studied in this species, but Beecher's (1942) data show that the nests can be relatively closely spaced. In Iowa, Weller (1961) found active nests as close as 5-6 m. Abbott (1903) and Coursen (1947) noted that annual variation in least bittern populations is extreme. This variation may depend to a great extent on local water conditions (Nolan 1952).

Nesting Cycle

The early phases of the nesting cycle from courtship to nest building have apparently never been witnessed in Illinois. Least bitterns appear to be relatively quiet birds, and the only call referred to in the Illinois literature is chatlike notes: "rock-rock" (Abbott 1903, Widmann 1907). Palmer (1962) referred to a dovelike cooing song uttered by the male in spring, but it is infrequently heard. Gault's extensive notes refer to the singing of this species only once (2 June 1912) in contrast to the numerous times when he heard the less common American bittern. Widmann (1907) noted that least bitterns become more active toward evening, the calls being heard especially then.

Whether yearling birds breed is apparently un-

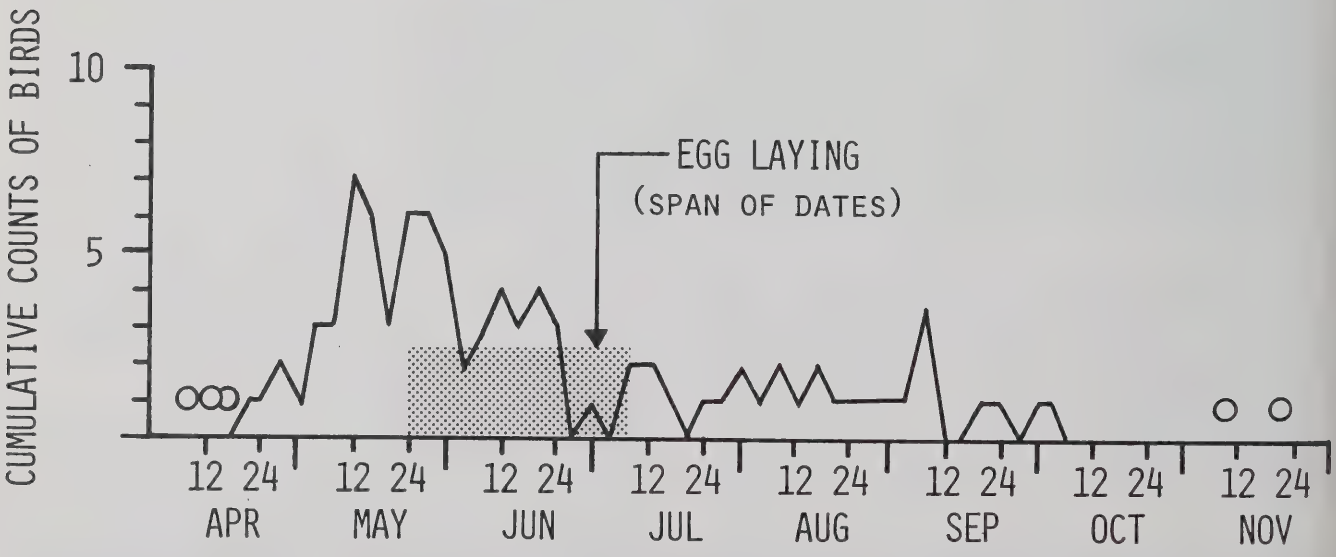

Fig. 50.—Cumulative counts of least bitterns from all recorded observations in Illinois. The shaded area shows the span of dates in which egg laying has been recorded. Circles indicate the earliest and latest records for the species in the state.

Least Bittern

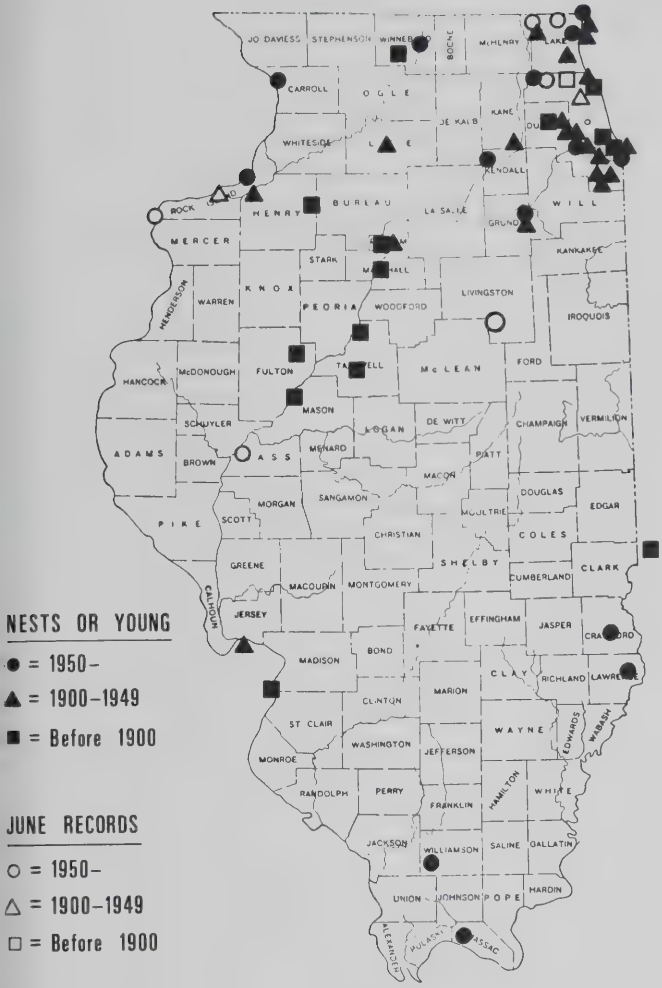

Fig. 51.—Distribution of breeding records of least bitterns in Illinois.

known. The nest is occasionally placed in a small shrub in the marsh, but much more typically, in the marsh vegetation itself (Abbott 1903). The nest is a rather frail flat platform, usually constructed of the reeds that surround the site folded over, about 30–91 cm above the water (Nelson 1876–1877, Murchison 1893*b*, Abbott 1903). On the Illinois River nests were rarely more than 30 cm above water (Barnes 1890*a*). Nests measured about 18 cm across and 8–15 cm in outside depth (Larsen 1893, Bennett 1953). The presence of the previous year's reed growth is apparently important as support and structure for the nest (Weller 1961).

The unmarked eggs range in color from pale blue, or greenish, to nearly white (Larsen 1893, Murchison 1893*b*, Bailey 1928). Eggs are usually laid on consecutive days, but some females may skip a day in making a clutch of five or more eggs (Weller 1961). The usual clutch has been said to be four eggs (Larsen 1893, Abbott 1903), but when we tabulated sets from the literature and museum records from northern and southern Illinois, there were as many 5-egg as 4-egg clutches, the distribution of all 78 clutches being: 7 eggs—1 set (1 percent), 6 eggs—4 (5 percent), 5 eggs—29 (37 percent), 4 eggs—29 (37 percent), 3 eggs—12 (15 percent), 2 eggs—3 (4 percent), with an overall average of 4.3 eggs per nest. Fifteen recent (since 1950) clutches from northern and southern Illinois had eight (53 percent) 5-egg sets, with only two sets (13 percent) each having 4, 3, and 2 eggs, and one (7 percent), 6 eggs, with an overall average of 4.3 eggs. These data were not collected specifically for clutch-size determinations, and may include some incomplete clutches. There were some references to nests with one egg, which were excluded from our tabulation.

The dates of fresh sets of eggs indicate that the laying season of the least bittern extends from at least 24 May to 8 July in northern Illinois, with the peak of laying in the first 2 weeks of June. Murchison (1893*b*) rarely found complete clutches in Henry County by 10 June and noted that few eggs showed more than 4 days of incubation on 14 June. At Calumet, Larsen (1893), who examined more than 50 nests in the first half of July, found only a few with eggs still fresh. An active nest with two eggs found by Peter Dring in Cook County on 1 August indicates that laying could have been *at least* as late as 15 July. Egg-laying dates for southern Illinois are very similar to those in the north. Murchison (1893*b*) noted that nearly all of the incubating birds he saw were males, but Weller (1961) observed that females did over half of the incubating.

In Iowa, Weller (1961) determined that incubation began with the first or second egg laid and took as long as 20 days for the first egg laid, but only 17–18 days for the last egg of the clutch. Larsen (1893) and Bailey (1928) found the incubating birds to be very shy, leaving the nest quietly when an observer approached. Young least bitterns apparently typically leave the nest long before they can fly and move about the marsh in the vicinity of the nest, returning to it occasionally. In Cook County, Lawrence Balch (unpublished) saw young bitterns leave their nest for brief but increasingly long periods at between 6 and 9 days of age. Bailey (1928) saw young leave the nest at 8 days of age though remaining nearby. The age of first flight of least bitterns is unknown (Palmer 1962).

No study of nesting success or productivity is available for any Illinois population of least bitterns. From 11 incomplete nest histories, nearly all from northeastern Illinois, we calculated the success of nests during laying and incubation to be 88 percent and of nests with young (to age 10 days) to be 66.5 percent and the overall success rate to fledging to be 59 percent. Successful nests produced 3.5 young per nest, but the average production of all nests was only 2.0 young per nest. Causes of nest failure were unknown.

Fall Migration

Relatively few least bitterns are seen after the nesting season (Fig. 50), and the number reported does not at all reflect the actual population. Few observers spend time in marshes, and the molting and departures of least bitterns go generally unnoticed. Loucks (unpublished 1894) saw many (possibly migrants) at Peoria on 17 August, and Dreuth's last record for Lincoln Park was 22 August (Clark & Nice 1950). Last-seen records of least bitterns often refer to September (Bennett 1953, Ford 1956, Woodruff 1907). An immature least bittern that we observed landed in Urbana on the night of 7–8 September and shows the migration definitely under way by that date. One killed on a television tower near Springfield on 1 October 1973 (Kleen 1974*a*) also indicates migration. It is as difficult to determine the end as the beginning of the migration of such a secretive species. The 3 October record for McGinnis Slough (Boulton & Pitelka 1937) may represent about the end of the regular migration, but there are at least two November records—9 November at Pere Marquette State Park (Comfort 1941) and 21 November in Cook County (Kleen 1977*a*)—the significance of which are uncertain.

Food

We have found but two observations on the food of the least bittern in Illinois. The stomach of an adult female of the dark form (so-called *neoxenus*) from northeastern Illinois contained two sunfish, each about 8 cm long (Eifrig 1915*a*). Also in the northeast, Bailey (1928) observed the feeding of young, and in typical heron fashion the young bitterns "mobbed" the adult, grabbing her bill in theirs to induce the discharge of food. The one item identified was a crayfish.

Specimen Data

The dark form of the least bittern—a relatively rare color phase of the species sometimes called Cory's least bittern—has been seen in Illinois at least once (Eifrig 1915*a*).

AMERICAN BITTERN

(Botaurus lentiginosus)

(Fig. 52 and 53)

Spring Migration

American bitterns are found rarely in Illinois in winter. There is at least one February record (Ford 1956), but the earliest indication of the spring migration is seen in mid-March. Musselman (unpublished 1927) found a bittern in Adams County on 14 March, and Sanborn (1935*a*) reported one in Chicago on 17 March. More typically, the species is not detected in Illinois until late March or April, and peak numbers are seen after mid-April (Fig. 54). Smith's (1930) latest spring record for the bittern at Urbana (a place with no known breeding population) was 18 May, which probably represents about the end of the passage of transients at that latitude.

Because bitterns are secretive and solitary, few are seen, and it is difficult to obtain a quantitative record of their migrations and other activities. As we have seen no more than one per day, we have plotted cumulative counts of all available observers to show when most birds have been seen (Fig. 54).

The migration is believed to be nocturnal, and a bittern killed during a storm on Lake Michigan on the night of 16 April 1960 may have been migrating (Segal 1960).

Distribution

The American bittern nests over much of temperate North America, wintering generally in Mexico and Central America (Fig. 53). In Illinois the range is very poorly known, and most of the nest records are old (Fig. 55). The available marsh and prairie habitats are dwindling seriously, and many of the old nesting areas are now gone. Additional nesting areas may be found, particularly on marshes of the major rivers, but most of the population is probably still in northeastern Illinois. In addition to the records plotted, July records for the Cuba area (Fulton County) may represent a nesting population (H. D. Bohlen unpublished).

The American bittern was an uncommon (about 0.2 percent of specimens identified) but regular component of Indian middens in all regions of Illinois, dating back to perhaps 8000 BC (Baker 1936 and 1941, Parmalee 1957, 1959, 1962*a*, and 1962*b*, Parmalee et al. 1972).

Nesting Habitats and Populations

In northeastern Illinois Beecher (1942) found American bitterns nesting most commonly in *Typha* (cattails), *Scirpus* (bulrushes), and *Carex lacustris* (sedge), noting that nests were absent in a year of high water (Beecher 1937). B. T. Gault's unpublished notes have frequent references to the bittern habitat in Du Page and Cook counties as "grassy marsh," and Gault mentions having found at least one nest in bulrushes. He also found one nest in an upland field above a marsh. Eaton (1879) stated that the nest was usually in the middle of a slough but sometimes at the edge of a small slough or wet area in a pasture.

Fig. 52 (Opposite page).—American bittern (captive bird). This brownish, streaked, chunky heron (about 55–60 cm long) superficially resembles immature night herons. The black mark on the side of the throat is a distinctive character.

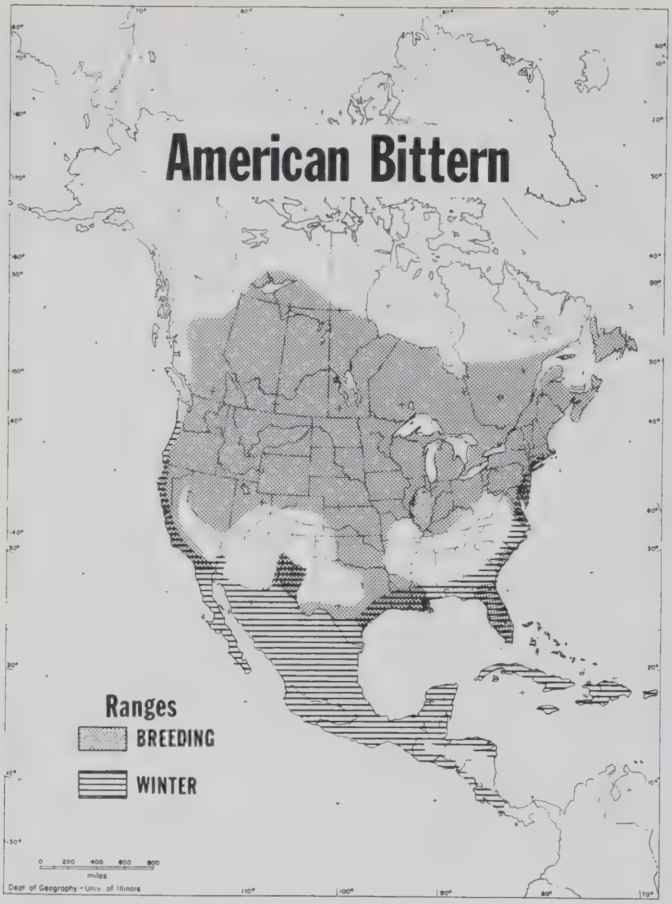

Fig. 53.—General distribution of the American bittern.

Nelson (1876–1877) believed the principal habitat of the American bittern to be prairie sloughs with rank swamp grass or rushes. His reference to the prairie may be pertinent to the general absence of bittern nesting records in the more forested areas of the state, though Woodruff (1907) stated that they nested on ponds in forests. We have seen only transients in low woodlands. Murchison (1893*b* and 1896) observed that bitterns preferred pond areas as nesting sites in Henry County. Nests are often over water just above water level. Murchison (1896) felt that the birds were not particular as to the depth of the water as long as there were plenty of rushes, including "round rushes," though he noted that the population of bitterns was obviously reduced in a very dry year. He also observed that American bittern nests were likely to be on the edge of the marsh. In southern Illinois Bennett (1953) found nests in dense cattails and noted that nests were widely scattered; this is the general impression of most observers. Euspiza (1876) stated that he never found nests within a "mile" of each other in the Peotone area, and in Henry County Murchison (1896) found nests no closer than "100 yards." At Calumet, Larsen (1893) found two nests about "50 feet" apart, but it is not absolutely clear that both were active. In northeastern Illinois, Beecher (1942) found one nest in 4.0 ha of cattails, and Bailey (1931) found a nest in a marsh 1.2–1.6 ha in extent. The minimum requirements are unknown, and such knowledge is increasingly important, as habitats, including marsh, are being carved into smaller and smaller pieces.

Populations of this species are apparently extremely variable from year to year, depending upon the condition of wetlands (Murchison 1896, Beecher 1937). In the cross-country censuses of 1957 we encountered American bitterns only in a Lake County cattail marsh, and our density figure of 10 bitterns per 40.5 ha is possibly exaggerated because of the small area (12 ha) covered. In 1958 we censused more (23 ha) of the same area and saw no bitterns. As very little (8 ha) marsh was censused in 1909, there are no useful comparative data with which to determine population trends. Nelson (1876–1877) called the American bittern a very common summer resident in northeastern Illinois, and the species was probably much more common then than it is now. This is evident in the number of transients seen in the Urbana area, where in the years 1903–1922 daily counts of American bitterns in April and May were commonly as high as three or four birds, and as many as six and seven were seen by such reliable observers as Frank Smith and F. C. Gates. In the same area now we feel fortunate to see one per day and do not see as many as six in the entire spring season. Causes of the decline other than the steady loss of habitat are unknown.

Nesting Cycle

The courtship displays of the American bittern (as apparently for herons generally) are spectacular, though rarely observed. Stout (1934) described such behavior, observed in June near Barrington. It involved a kind of rhythmic circling dance by one bird (male?) around the other, and posturing displays of feathers, including a "star" of white feathers near the head. The ceremony continued for 40 minutes. Whether vocalizations accompanied the display was not stated, but the species does make impressive sounds. Butler (1897) described three vocalizations: (1) soft guttural notes audible only at very close range, (2) the song, phoneticized "plum-pudden" with the accent on "pud," the phrase repeated four to eight times, and (3) the so-called stake-driver sound, phoneticized "ka-whack, ka-whack," which Murchison (1896) compared to the sound made by driving a nail into a board. Eaton (1879) phoneticized the "song" as "chunk-a-lunk-chunk, quank" and stated that it could be heard a long distance on calm clear nights in spring. Hunter (1936) observed a bittern "singing" for 15 minutes, as it stood motionless. To produce the sound—"plunk-er-lunk"—the bird gulped air with a forward motion of the head

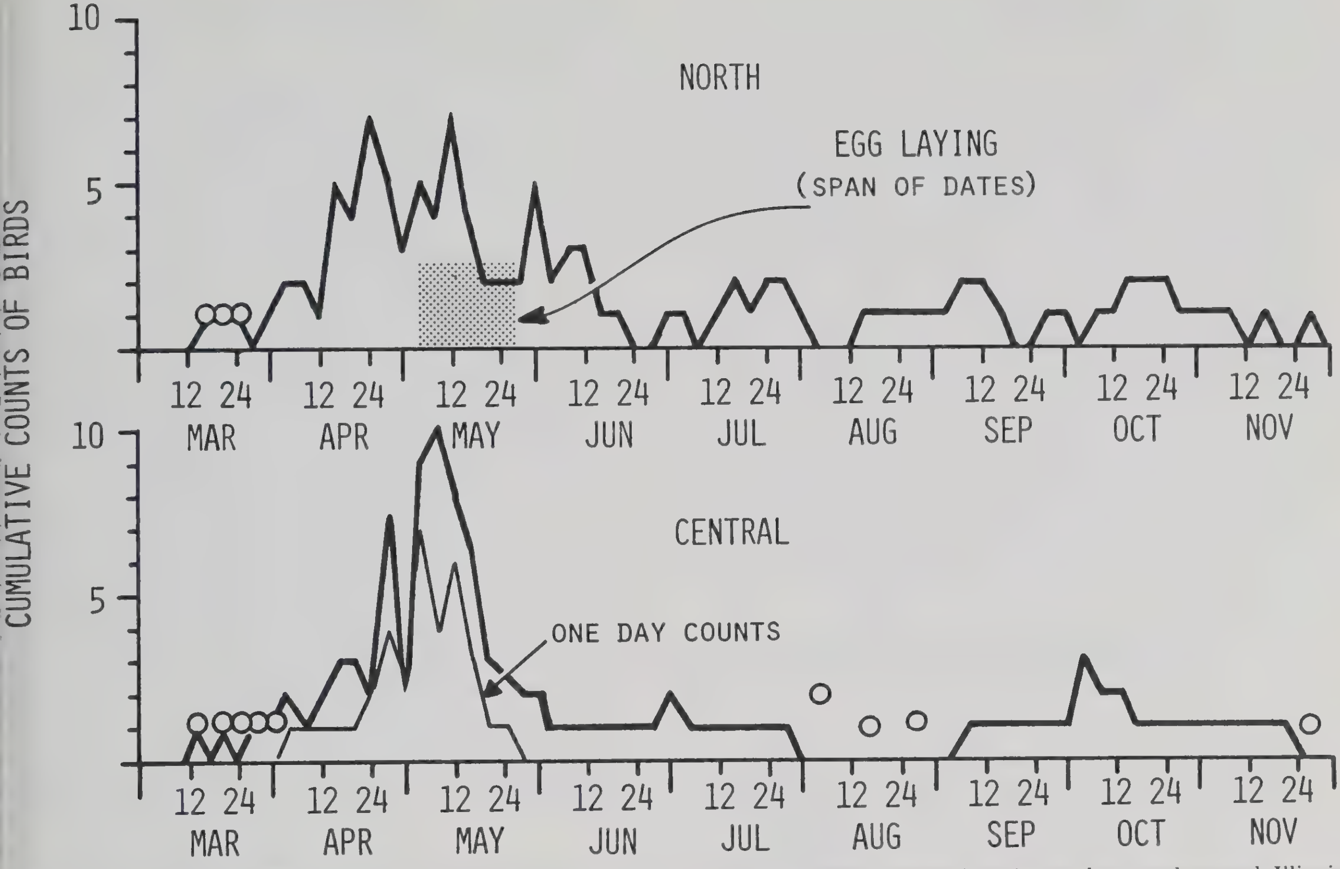

Fig. 54.—Cumulative counts (heavy line) of American bitterns from all recorded observations in northern and central Illinois. The thin graph line represents 1-day counts made early in the 1900's by Frank Smith and his students near Urbana. Circles represent isolated 1-day counts in recent years. The shaded area shows the span of dates in which egg laying has been recorded. There are too few data for southern Illinois to plot.

and snapping of the bill, after which it expelled the air rapidly. A fourth sound made by the bittern is a single harsh croak—"quark"—apparently a kind of alarm note (Eaton 1879, Murchison 1896). The sound of the song is referred to as "pumping" or "booming," and Benjamin Gault (unpublished 1889–1916) often heard the sound between 23 April and mid-June in Du Page County, frequently at night. In the same season William Loucks (unpublished 1892) heard the song frequently in Tazewell County.

Nest building has not been observed, but descriptions of nests range from "a mere depression in the ground" (Euspiza 1876) to "a bulky platform of rushes" (Larsen 1893). The most elaborate nest found by Murchison (1893*b*) was a structure 61 × 46 cm across and 20 cm thick (presumably outside depth), but, on average, nests measured 38 × 25 × 10 cm. The nests are built of the dead stalks of the surrounding vegetation—usually bulrushes, cattails, sedges, and similar plants. Murchison (1896) believed the birds also built nestlike platforms on which they rested.

The eggs are unspotted and range in color from dark cream to yellowish drab to greenish (Eaton 1879, Murchison 1896). The average dimensions of 23 eggs from Henry County were: 50.0 × 36.8 mm (Murchison 1896). Murchison observed one nest in which the second and third eggs were laid on consecutive days. Data on 38 clutches of American bittern eggs from northern Illinois referred to mainly in the older (pre-1900) literature showed the following distribution: 7 eggs—1 clutch (3 percent), 6 eggs—1 (3 percent), 5 eggs—10 (26 percent), 4 eggs—18 (47 percent), 3 eggs—5 (13 percent), and 2 eggs—3 (8 percent). Eaton (1879) pointed out that a clutch of seven eggs was very unusual and that most nests had four. There are no recent data on clutch size. Mainly from the dates of fresh eggs, we estimated that the laying season extends at least from 4 to 28 May in northern Illinois (Fig. 54). Two eggs in a nest found on 26 July in the Palos Hills area (Peter Dring unpublished) could have been laid at least as late as 1–2 July, i.e., much later than shown in Fig. 54. In Quebec, Mousley (1939) found the incubation period to be 24 days, beginning with the first egg laid. The young stayed in the nest about 2 weeks, but the age of first flight is still unknown (Palmer 1962).

The only indication of productivity is Bennett's (1953) observation that four pairs of birds observed in southern Illinois, 1950–1952, each produced two young, though to what age they were reared was not made clear. In northern Illinois, Gault (unpublished) found single young bitterns out of the nest in June and early July.

Fall Migration

Compared with the numbers seen in spring, relatively few American bitterns are seen following the nesting season, and it is not known when most of the fall migration occurs (Fig. 54). Records of six bitterns seen in East St. Louis on 25 July (Wilhelm 1954), one in Alexander County in late July (Gower 1932), and two at Cape Girardeau on 24 August (Jones 1934) could have been either local breeding birds or migrants. A male American bittern (INHS specimen AR b-1) killed with other migrants at a television tower in east-central Illinois on the night of 8–9 September 1967 shows the migration to be definitely in progress by that date. The specimen was very fat and in fresh plumage, the molt also having been completed by that date. At a tower in the same region another bittern was killed on the night of 6–7 October 1955 (Brewer & Ellis 1958). Gault's (1901) latest record in northeastern Illinois during an 8-year period was 19 October. Coursen (1947) indicated also that the bittern population leaves northern Illinois in October, but noted that a few sometimes remain until the marshes freeze. There are a number of records for November, spanning almost the entire month even in northern Illinois (Fig. 54, Ferry 1898, Lincoln 1927, Boulton & Beecher 1940, Clark & Nice 1950, and others). Some of these late fall records, and also winter records, may be attributable to the crippling of birds by hunters (see Musselman 1926), but an X-ray study of fall specimens is needed to determine the incidence of such cases.

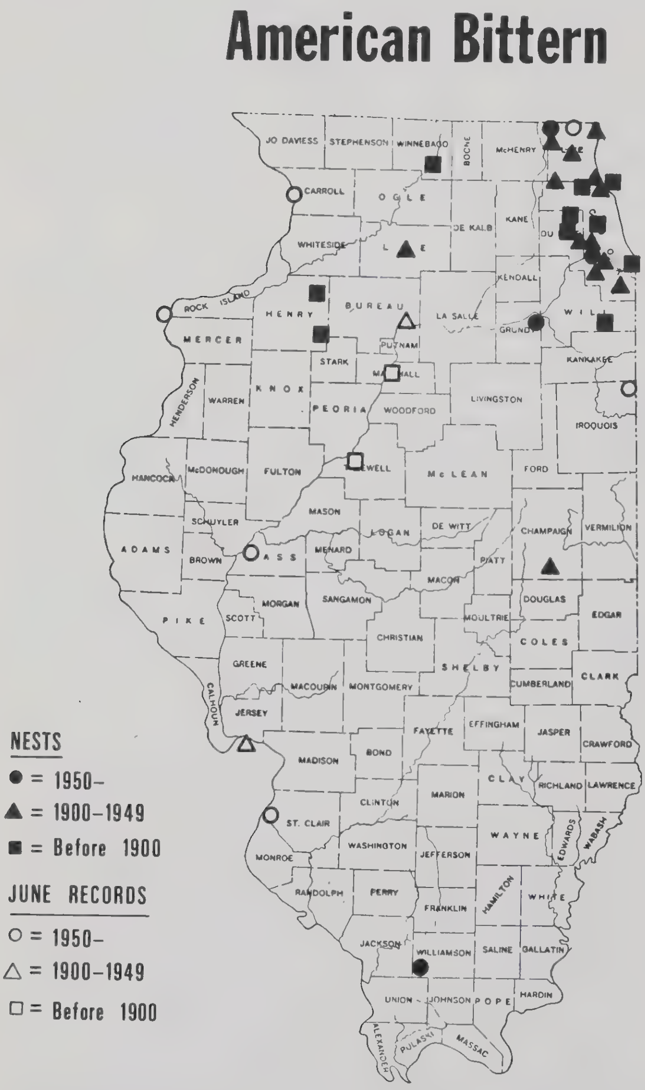

Fig. 55.—Distribution of breeding records of American bitterns in Illinois.

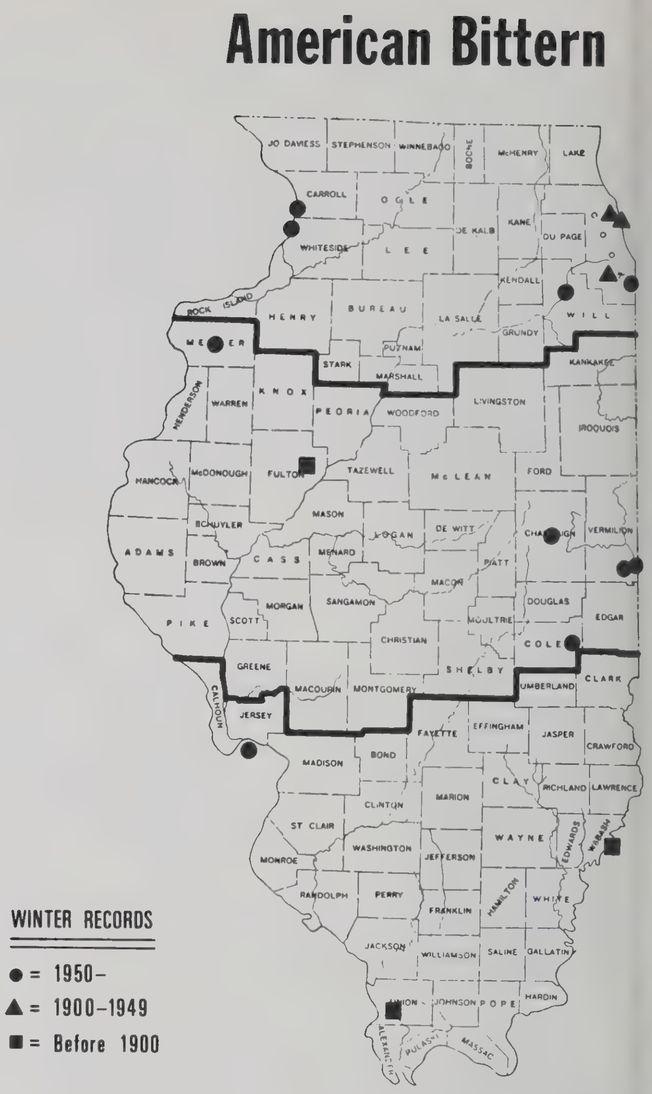

Fig. 56.—Distribution of winter (15 December–1 February) records of American bitterns in Illinois.

Winter Records

Cooke (1885) and Ridgway (1881) indicated that the American bittern was a winter resident of southrn Illinois at least in mild winters, but there are few pecific records (Fig. 56) and no data on the size of he population involved. In addition to the records lotted, there is a winter record for Sangamon County f uncertain locality (Kleen 1974*b*). Bitterns were ot detected in winter on the cross-country censuses ither in 1906–1907 or 1956–1958, and we doubt that here is a sizeable or consistent winter population in ny part of the state. In view of the species' secretive ature, it may merely go undetected.

ood

We have found but two references to the food of he American bittern in Illinois. Gault (unpublished 894) saw one eating a frog in July at Lisle, and we bserved one swallow a large leopard frog whole in May. Both observations were made in wet woods.

pecimen Data

Brodkorb (1936) suggested that there are recognizable eastern and western populations of the American bittern. He considered that specimens (12) from northern Illinois represented the eastern form (*B. l. entiginosus*). Presently, the proposed races are not recognized by the American Ornithologists' Union.

A male specimen killed at a television tower in Vermilion County on the night of 8–9 September 1967 weighed 818.0 grams and was very fat.

WOOD STORK *(Mycteria americana)*

Wood storks (ibis) have wandered up the Mississippi and other large streams in southern Illinois irregularly but sometimes in considerable numbers (Fig. 57 and 58). Kennicott (1856) reported it common and thought that it probably bred in southern Illinois, though there was no proof of it, and now the nearest known breeding colonies in this country are in the southeastern Gulf states. It was also considered common by Ridgway (1874) and Nelson (1876 and 1877). Hurter (1881) wrote of 50 near St. Louis in "Marion County," Illinois, and "hundreds" were reported along the Illinois River (latitude 39°15′) in 1889 (H.F.A. 1889). In other years only a few were reported: nine seen near East St. Louis in 1879 (Widmann 1880) and nine on the Wabash River 10 miles west of Mt. Vernon, Indiana (Evermann 1889). A number were reported in 1925: 50 in Jefferson County (Carson 1926), 25 in Lawrence County, and 1 found dead in southwest Richland or northeast Wayne County (Eaton 1926).

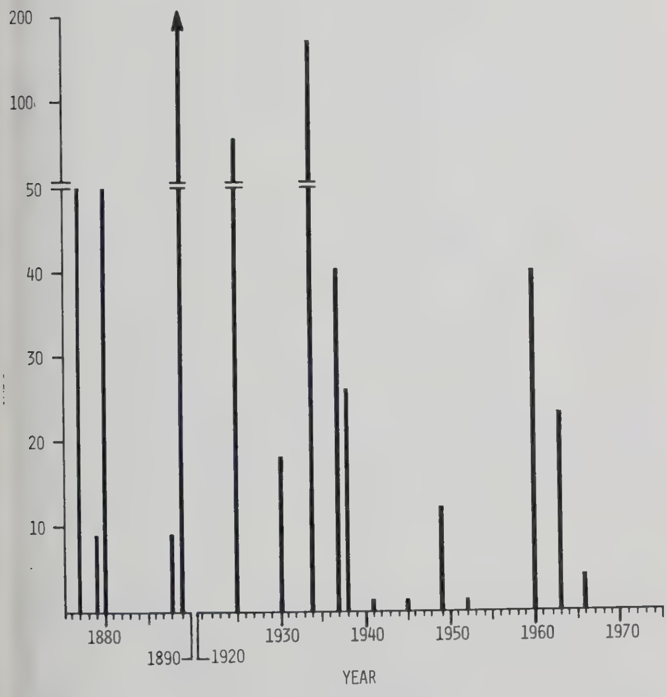

Fig. 57.—Numbers of wood ibis (storks) recorded in Illinois in different years.

Wood Ibis

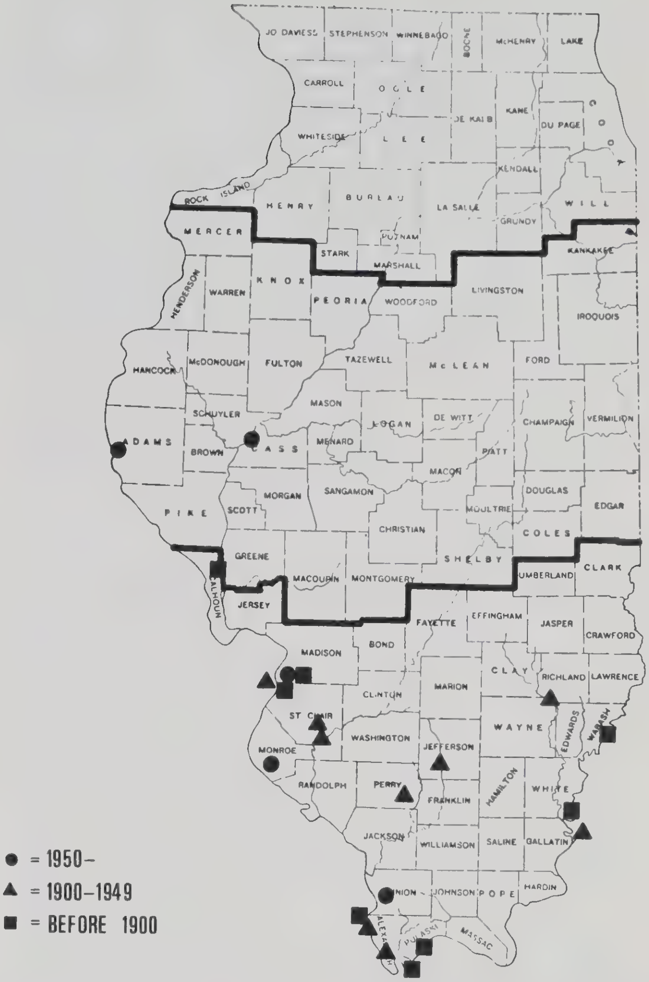

Fig. 58.—Distribution of sightings of wood ibis in Illinois. None of these represent breeding records.

The next report of the species in or near Illinois was in 1930, when 18 were seen near the Ohio River in Posey County, Indiana (Hicks 1934). Large numbers occurred near Illinois in 1934, when 130 or more were seen near University City, Missouri, and 44 near Cape Girardeau (Jones 1934). Thirty-five to forty wood storks were seen in Illinois across the river from Cape Girardeau in 1937 (Bolen 1937, Jones 1937*d*). In 1938, 7–26 were reported in the area around Freeburg and New Athens (Short 1938, Jones 1938*b*). George (1968) reported the species in Alexander County in 1941, in Perry County in 1945, and in Jackson County in 1949 (see also Mayfield 1950*a*). A single bird was seen at Horseshoe Lake, Madison County, in 1952 (Comfort 1952). Forty wood storks were seen by Paul Heye (Comfort 1961*a*) in Union County in 1960. Twenty-three to twenty-six were seen in Illinois near St. Louis in 1963 (Petersen 1963, Fleig 1971). The last report to date of the species in Illinois is of two seen on the Illinois River and two seen 3 days later at Quincy in September 1966 (Petersen 1967*a*, Musselman 1968*b*).

All of the Illinois records for wood storks, with one exception, have occurred in late summer from late July (Carson 1926) to 18 September (Heye *in* Comfort 1961*a*). The report of two birds near Quincy in May 1967 (Petersen 1967*b*) may be an error, since we can find no mention of the species in Musselman's unpublished daily notes for May 1967 nor does Musselman (1968*b*) mention them. Wood storks have often appeared in Illinois in dry seasons, and when seen, are around stagnant bodies of water in or near forest.

In general, the number of wood storks seen in Illinois seems to be declining.

GLOSSY IBIS *(Plegadis falcinellus)* and WHITE-FACED IBIS *(Plegadis chihi)*

Dark ibis of the genus *Plegadis* are still recognized as two species by the American Ornithologists' Union. The two species are indistinguishable except in the nuptial plumage of the adults. In other plumages, glossy and white-faced ibis are not readily separable even in the hand except perhaps by bill length. Even Ridgway later questioned his identification of the 1880 Hurter specimen (Brewer 1958*a*). Thus, it is impossible to be certain which species is actually represented by the many Illinois sight records of dark ibis (Fig. 59).

Of over 30 reports of dark ibis in Illinois since Nelson (1876–1877), only a few have identified the birds as white-faced ibis; Comfort (1953) recorded five seen near Staunton, Macoupin County, in September 1952; one was photographed at Powderhorn Marsh, Cook County, in May 1965 (Balch 1965); two were seen in late April 1967 near Lacon, Marshall County (Princen 1968); and one was reported at Gorham, Jackson County, in May 1972 (H. D. Bohlen unpublished). Besides these records, there is the

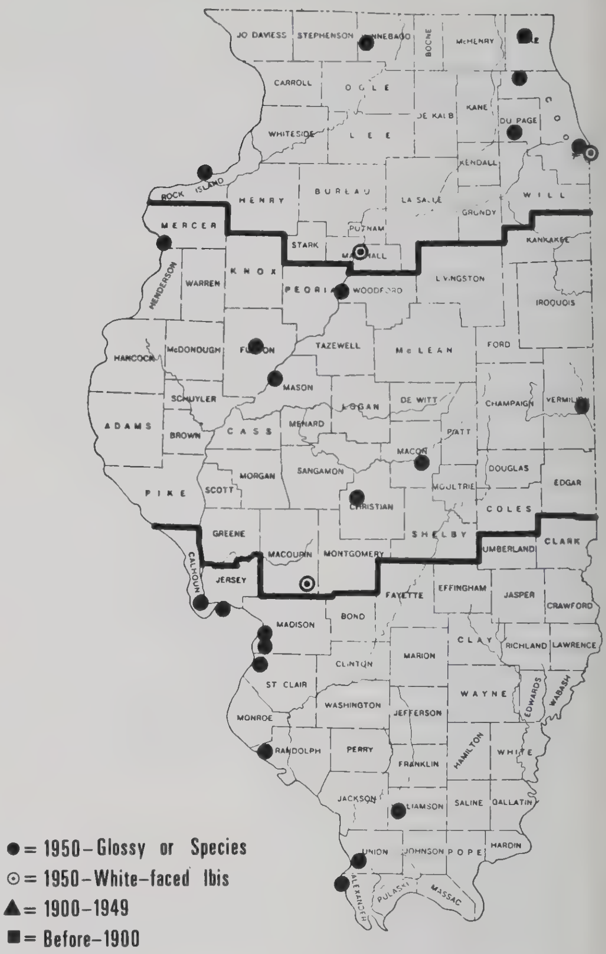

Fig. 59.—Distribution of sightings of glossy and white-face ibis in Illinois. None of these represent breeding records.

1880 Hurter specimen—taken near St. Louis—which may be of this species. Widmann (1907) writes of white-faced ibis specimen taken in St. Charles County Missouri.

Records of "glossy" ibis for northern Illinois include the following localities: northeastern Illinoi (Nelson 1876-1877), Calumet Lake (Nolan 1953b Graber 1962, Petersen 1969), Naperville (Hoger 1962), Barrington (Hoger 1963), Sparland (Fawk 1966*a*), Keithsburg (Fawks 1970*b*), and Grayslak and Pecatonica (Kleen 1975*c*). There is also a recor for Powderhorn Marsh in Indiana (B. P. Brown 1966 and one for Credit Island in Iowa (Greer 1957).

Central Illinois records of dark ibis include thos for Lake Decatur (Nolan 1956), Cuba (Fawks 1970*a*) Lake Kincaid and Mossville (Kleen & Bush 1972 and 1972*c*), Chillicothe (H. D. Bohlen unpublished) Danville (Kleen 1975*c*), and Havana (Kleen 1976*b*)

In southern Illinois and contiguous areas, th glossy ibis has been reported in these places: St Louis area and St. Charles County, Missouri (Shor 1939, Comfort 1955*b*, Petersen 1966*b* and 1969, Fawk

1971*b*); near East St. Louis (Mayfield 1951, Anderson 1971*b*); near Fort Chartres and Swan Lake (Anderson 1964*b*); in Alexander County, Illinois, near Cape Girardeau (Anderson 1971*a*); near Mitchell (Fawks 1971*b*); at Crab Orchard Wildlife Refuge (Kleen & Bush 1973); and at Union County Conservation Area (Kleen 1974*a*).

The white-faced ibis breeds spottily over much of the western United States. The glossy ibis breeds in the southeastern USA in very limited numbers. Palmer (1962) states that the glossy ibis *(P. falcinellus)* may actually be a fairly recent arrival from the Old World, as authentic breeding records for this country date back only to the 1880's. Both of these ibis are noted for wandering widely, and occur in Illinois only as wanderers. The greatest number of sightings in Illinois have occurred in late May, but dark ibis have been reported here as early as 27 February (Hurter 1881) and as late as 25 October (Fawks 1966*a*). Ryder (1967) writes that more white-faced ibis have been seen extralimitally before the breeding season than after, and suggests drought in nesting areas as a causal factor.

WHITE IBIS *(Eudocimus albus)*

White ibis have wandered into Illinois on several occasions. Ridgway (1878) thought that he had seen a flock of seven or eight white ibis on 8 May 1878 near Mt. Carmel. According to Widmann (1907), four white ibis were reported at Quincy (no date given). In 1917 one was collected at Swan Lake, Greene County, in August (Smith & Parmalee 1955).

More recently, an immature (?) white ibis was seen at Marias Temps Clair marshes, which lie in Missouri just south of Elsah, Illinois, on 26 August 1962 (Anderson 1962*c*). Two were seen at Moredock Lake, Monroe County, in July 1963 (Anderson 1963*b*). The species was also reported from Kaskaskia State Park on 4 July 1963 and from Fults from 15 July to 3 August 1963 (Anderson 1964*c*). An adult bird was seen on the Mississippi River levees of Monroe County on 2 and 3 May 1964 (Hoger 1964, Anderson 1964*a*). An immature white ibis was observed with little blue herons at Gilbert Lake, Jersey County, on 6 August 1977 (H. D. Bohlen unpublished).

Since this ibis is nonmigratory, birds appearing in Illinois may have been caught up (entrained) in flocks of northward-wandering herons, which were their associates in rookeries during the breeding season.

ROSEATE SPOONBILL *(Ajaia ajaja)*

It is interesting that the only specimen of this species for the state of Illinois is a skeleton found in a Hopewell Indian grave of the period 150–250 AD in Calhoun County near Kampsville (Parmalee & Perino 1970). It may have been that such a rare and unusual bird was a great trophy, which was buried with its collector.

Musselman (1968*a*) refers to spoonbill remains from Indian mounds near Peoria; however, we are unable to find any other reference to this find. Ridgway (1880) mentions specimens taken in the Mississippi bottoms of Illinois below St. Louis in the 1860's. Cory (1909) gives the date as about 1859. The collector, a Mr. Wolle, said that it was not uncommon there at that time. A roseate spoonbill was collected by O. C. Poling in Adams County on 28 April 1887 (Musselman 1921). Whether this is the bird referred to earlier by Musselmann (1916–1917) is unknown. The location of this specimen is unknown.

AMERICAN FLAMINGO
(Phoenicopterus ruber)

Of accidental occurrence, the flamingo has been recorded a few times in Illinois. In 1959 a flamingo was reported in Adams County near La Grange, Missouri, on 1 September (Harford 1959). Later that year one was seen at Banner, Fulton County, on 28 September by F. Luthy (Mumford 1960*a*) and on 3 October at Ingraham Lake near Snicarte, Mason County, by A. Russ (Luthy unpublished). All of these reports could have been of a single bird moving about. There was an additional report of one on 8 August 1959 at Havana, Mason County (Mumford 1960*a*); however, since this information was supposedly from T. E. Musselman, who has no record of it in his field notes, we wonder if it could be an error in reporting.

Another series of flamingo sightings were of a bird that escaped from the Lincoln Park Zoo in Chicago on Memorial Day 1966 and was seen a number of times in the area until September (Petersen 1966*b*, Schulze 1966).

LITERATURE CITED

Abbott, G. A. 1903. Nesting of the least bittern. Birds and Nature 14 (2) :71.

Anderson, R. 1962*a*. Spring survey. Bluebird 29 (2) :14–20.

———. 1962*b*. Summer survey. Bluebird 29 (3) :19–23.

———. 1962*c*. Fall survey. Bluebird 29 (4) :21–28.

———. 1963*a*. Spring survey. Bluebird 30 (2) :20–28.

———. 1963*b*. Summer survey. Bluebird 30 (3) :16–23.

———. 1963–1964. Fall survey. Bluebird 30 (4) :13–21.

———. 1964*a*. Spring survey—March 1 to May 31, 1964. Bluebird 31 (2) :8–15.

———. 1964*b*. Fall survey. Bluebird 31 (4) :14–19.

———. 1964*c*. Observations from southern Illinois. Audubon Bulletin 129:18.

———. 1971*a*. Bird survey. Bluebird 38 (1) :2–4.

———. 1971*b*. Bird survey. Fall 1970. Bluebird 38 (4) :7–11.

———. 1974*a*. Spring survey—April 1 through May 31. Bluebird 41 (3) :3–5.

———. 1974*b*. Summer survey—June 1 through July 31. Bluebird 41 (4) :6–7.

Angus, H. L. 1937. The migration and distribution of the great blue heron in Illinois. Illinois State Academy of Science Transactions 30 (2) :293–294.

Anonymous. 1911. Night herons are found. Oologist 28 (5) :83.

———. 1933. Notes. Chicago Academy of Sciences. Program of Activities 4 (4) :n.p.

———. 1946. [Untitled.] Audubon Bulletin 60:16.

———. 1949. Cape Girardeau. Bluebird 16 (2) :n.p.

———. 1951. Briefs. Bluebird 18 (10) :n.p.

———. 1955. [Untitled.] Inland Bird Banding News 27 (5) :45.

———. 1977. Field reports. Iowa Bird Life 47 (2) :57.

Bailey, A. M. 1928. Photographing the least bittern. Audubon Bulletin 19:8–10.

———. 1931. Bird life of a roadside marsh. Audubon Bulletin 21:38–39.

Baker, F. C. 1936. Remains of animal life from the Kingston kitchen midden site near Peoria, Illinois. Illinois State Academy Science Transactions 29 (2) :243–246.

———. 1941. A study in ethnozoology of the prehistoric Indians of Illinois. American Philosophical Society Transactions 32 (2) :51–77.

Balch, L. G. 1965. Field notes—September 1965. Audubon Bulletin 135:11.

———. 1972. Lake Michigan summary/fall of '71. Audubon Bulletin 162:19–20.

Barnes, R. M. 1890*a*. A day's egging in an Illinois swamp. Ornithologist and Oologist 15 (1) :10.

———. 1890*b*. List of birds breeding in Marshall Co., Ill. Ornithologist and Oologist 15 (8) :113–116.

———. 1909. They are gone. Oologist 26 (11) :183–185.

———. 1912. Breeding birds of Marshall Co., Ill. Oologist 29 (8) :325–328.

———. 1917. A rare visitant. Oologist 34 (9) :162.

———. 1926. American egret. Oologist 43 (2) :28.

———. 1927. A half day on the Illinois river. Oologist 44 (7) : 82–86.

———. 1936. April. Oologist 53 (4) :37.

Bartel, K. E. 1934*a*. An Illinois trip. Inland Bird Banding News 6 (3) :9–10.

———. 1934*b*. An Illinois trip. Oologist 51 (10) :126–127.

———. 1935. Great blue heron studies. Inland Bird Banding News 7 (2) :3.

———. 1937. Fifth annual great blue heron banding trip. Inland Bird Banding News 9 (3) :2–4.

———. 1942. Banding events of 1941. Audubon Bulletin 41: 12–14.

———. 1943. The swamp. Audubon Bulletin 45:7–9.

———. 1952. Summer banding. Inland Bird Banding News 24 (5) :27, 29.

———. 1958. A distant recovery. Inland Bird Banding News 30 (4) :36.

———. 1972. Seventy-second Christmas bird count. 564. Morris–Wilmington, Ill. American Birds 26 (2) :375–376.

———. 1976. My 42 years of bird banding. Inland Bird Banding News 48 (2) :55–65.

Beecher, W. J. 1937. Meadows, marsh, and oak-hickory island. Bird-Lore 39 (5) :374–375.

———. 1942. Nesting birds and the vegetation substrate. Chicago Ornithological Society, Chicago. 69 p.

Bellrose, F. C. 1938. Yellow-crowned night heron breeding in northern Illinois. Auk 55 (1) :122.

———. 1939*a*. The American egret in the Illinois River valley. Audubon Bulletin 30:1–5.

———. 1939*b*. American egret nesting along the Illinois River. Auk 56 (1) :73–74.

———. 1941. Unusual water- and shorebirds in the Illinois River valley. Auk 58 (4) :574–576.

Bennett, E. V. 1953. Nesting birds of the shoreline and islands of Crab Orchard Lake with particular reference to the Canada goose, *Branta canadensis* (Linnaeus) and the eastern red-wing, *Agelaius phoeniceus* (Linnaeus). M.S. Thesis. Southern Illinois University. 45 p.

Bent, A. C. 1926. Life histories of North American marsh birds. U.S. National Museum Bulletin 135. 385 p.

Bjorklund, R. G. 1975. On the death of a midwestern heronry. Wilson Bulletin 87 (2) :284–287.

———, and B. Canterbury. 1971. Band recoveries from the Worley and Clear Lake heronries. Peoria Academy of Science Proceedings 4:27–28.

———, J. P. Miller, and A. Szluha. 1967. Great horned owl, *Bubo virginianus*, and barred owl, *Strix varia*, on an Illinois River heronry. Illinois State Academy of Sciences Transactions 60:107–108.

Black, C. T. 1935. Ecological relations of the birds of the Champaign-Urbana region. M.S. Thesis. University of Illinois. 46 p.

Blake, E. R. 1948*a*. Middle-western region. Audubon Field Notes 2 (1) :14–15.

———. 1948*b*. Middle-western region. Audubon Field Notes 2 (3) :142–143.

Blocher, A. 1926. Large sets. Oologist 43 (4) :49–50.

———. 1937. Desertion. Oologist 54 (6) :67–70.

Bolen, H. R. 1937. [Letter to Editor.] Bluebird 4 (9) :93.

Boughner, J. L. 1960. Field notes—Spring, 1960. Audubon Bulletin 114:13.

Boulton, R., and W. J. Beecher. 1940. Chicago region. Bird-Lore 42 (2) :218–219 (Supplement).

———, and F. A. Pitelka. 1937. Chicago region. Bird-Lore 39 (6) :473–474.

———, and ———. 1938. Chicago region. Bird-Lore 40 (6) : 464–465.

———, and ———. 1939. Chicago region. Bird-Lore 41 (1) : 57–58.

Brewer, R. 1958*a*. Some corrections to "A distributional check list of the birds of Illinois." Audubon Bulletin 106:9–11.

———. 1958*b*. Breeding-bird populations of strip-mined land in Perry Co., Ill. Ecology 39 (3) :543–545.

———, and J. A. Ellis. 1958. An analysis of migrating birds killed at a television tower in east-central Illinois, September 1955–May 1957. Auk 75 (4) :400–414.

Brodkorb, P. 1936. A new subspecies of bittern from western North America. University of Michigan Museum of Zoology Occasional Papers 333. 4 p.

Brown, B. P. 1966. Chicago lake front migration—fall 1966. Audubon Bulletin 140:11–15.

Brown, W. H. 1962. General notes reports. Iowa Bird Life 32 (2) :42–44.

———. 1963*a*. General notes reports. Iowa Bird Life 33 (2) : 37–41.

———. 1963*b*. Field reports. Iowa Bird Life 33 (3) :73–76.

———. 1964. Field reports. Iowa Bird Life 34 (1) :19–22.

———. 1965. Field reports. Iowa Bird Life 35 (3) :86–90.

———. 1966. Field reports. Iowa Bird Life 36 (3) :81–84.

———. 1969. Field reports. Iowa Bird Life 39 (2) :38–41.

———. 1974. Field reports. Iowa Bird Life 44 (2) :43.

Brownell, H. 1916. St. Charles. Audubon Bulletin, Spring:47.

Butler, A. W. 1897. Birds of Indiana. Pages 515–1187 *in* 22nd Annual Report of the Department of Geology and Natural Resources of Indiana for 1897. [Indiana Academy of Sciences Proceedings for 1908.]

———. 1934. White herons in Indiana. Indiana Academy of Sciences Proceedings 44:228–230.

Calef, R. T. 1953. Ecological analysis of the flora and vertebrate fauna of Funks Forest Natural Area, McLean Co., Ill. Master's Thesis. University of Illinois. 85 p.

Campbell, M. 1972. 559. Forest Glen Preserve, Ill. American Birds 26 (2) :373–374.

Carlander, K. D. 1950. Handbook of freshwater fishery biology. Wm. C. Brown Company, Dubuque, Iowa. 281 p.

———. 1969. Handbook of freshwater fishery biology. Volume I. Iowa State University Press, Ames, Iowa. 752 p.

Carson, M. P. 1926. The wood ibis in Jefferson County, Illinois. Bird-Lore 28 (3) :195–196.

Chaniot, G. E. 1959. 344. Decatur, Ill. Audubon Field Notes 13 (2) :187.

———, and R. Kirby. 1955. Grazed stream bottomland. Audubon Field Notes 9 (6) :413.

Chase, V. H. 1899. Bird's nests. No. 2. Green heron. Wilson Bulletin 11 (2) :17–19.

Clark, C. T., and M. M. Nice. 1950. William Dreuth's study of bird migration in Lincoln Park, Chicago. Chicago Academy of Sciences Special Publication 8. 43 p.

Coffey, B. B. 1943. Post-juvenile migration of herons. Bird-Banding 14 (1&2) :34–39.

Comfort, J. E. 1941. Webster Groves notes. Bluebird 8 (10) : 72; 8 (12) :86–87.

———. 1949. St. Louis area. Bluebird 16 (10) :n.p.

———. 1951. St. Louis area. Bluebird 18 (12) :n.p.

———. 1952. St. Louis area. Bluebird 19 (10) :n.p.

———. 1953. A year's review of 1952. Bluebird 20 (3) :n.p.

———. 1955*a*. St. Louis area birding. Bluebird 22 (1) :n.p.

———. 1955*b*. Birds of the St. Louis area. Bluebird 22 (6) :n.p.

———. 1957. Summer in the St. Louis area. Bluebird 24 (7) : n.p.

———. 1958*a*. The late spring in St. Louis. Bluebird 25 (5) : n.p.

———. 1958*b*. Early summer St. Louis area birding. Bluebird 25 (7) :n.p.

———. 1959. Nesting birds of the St. Louis area. Bluebird 26 (7) :n.p.

———. 1961*a*. The St. Louis area. Bluebird 28 (1) :17.

———. 1961*b*. St. Louis. Bluebird 28 (3) :22.

———. 1962. An amazing cattle egret report. Bluebird 29 (3) :24.

Cooke, M. T. 1938. Returns of banded birds: recoveries of banded marsh birds. Bird-banding 9 (2) :80–87.

Cooke, W. W. 1885. Mississippi valley migration—spring 1883. Ornithologist and Oologist 10 (12) :177–178.

———. 1888. Report on bird migration in the Mississippi valley in the years 1884 and 1885. U.S. Department of Agriculture, Division of Economic Ornithology Bulletin 2. 313 p.

———. 1913. Distribution and migration of North American herons and their allies. U.S. Department of Agriculture Biological Survey Bulletin 45. 70 p.

Cory, C. A. 1909. The birds of Illinois and Wisconsin. Field Museum of Natural History Publication 131, Zoological Series 9. 766 p.

Coursen, C. B. 1947. Birds of the Orland Wildlife Refuge. Turtox News (Supplement). 30 p.

Crosby, G. T. 1972. Spread of the cattle egret in the western hemisphere. Bird-banding 43 (3) :205–212.

Cunningham, J. W. 1941. Missouri region. Audubon Magazine 43 (5) :474.

———. 1945. Missouri region. Aububon Magazine 47 (5) :50–51.

———. 1947. Missouri region. Audubon Field Notes 1 (1) :11–12.

———. 1948. Missouri region. Audubon Field Notes 2 (1) :17–18.

———, and R. Spotswood. 1942. Missouri region. Audubon Magazine 44 (6) :9–10 (Supplement).

Deane, R. 1897. Illinois. Auk 14 (1) :24–26

Dillon, S. T. 1971. Additional avian species seen at McGraw Wildlife Foundation. Audubon Bulletin 159:18–20.

DuMont, P. A. 1932. The American egret in Iowa in 1932. Iowa Bird Life 2 (4) :48–50.

———. 1935. The American egret and the little blue heron in Iowa. Iowa Bird Life 5 (3) :43.

———. 1947*a*. Middlewestern region. Audubon Field Notes 1 (4) :154–156.

———. 1947*b*. Middlewestern region. Audubon Field Notes 1 (5) :177–179.

———, and E. T. Smith. 1945. Middle-western region. Audubon Magazine 47 (5) :48–50 (Supplement).

———, and ———. 1946. Middle-western prairie region. Audubon Magazine 48 (5) :123–124 (Supplement).

Dusi, J. L. 1967. Migration in the little blue heron. Wilson Bulletin 79 (2) :223–235.

Dyke, A. 1953. 280. Princeton, Ill. Audubon Field Notes 7 (1) : 137.

Eaton, D. H. 1879. Nest and eggs of the American bittern *(Botaurus minor)*. Ornithologist and Oologist 4 (10) :73–74.

Eaton, S. H. 1926. Wood ibis in Illinois. Auk 43 (1) :90.

Eifert, V. S. 1949. A lake for the Lincoln country. Audubon Magazine 51 (4) :218–225.

Eifrig, C. W. G. 1911. A paradise for longspurs. Wilson Bulletin 23 (1) :49–52.

———. 1913. Notes on some of the rare birds of the prairie part of the Chicago area. Auk 30 (2) :236–240.

———. 1915*a* Cory's least bittern in Illinois. Auk 32 (1) :98–99.

———. 1915*b*. Field notes from the Chicago area. Wilson Bulletin 27 (3) :417–419.

———. 1917. Field notes from the Chicago area for 1916. Wilson Bulletin 29 (1) :43–45.

———. 1919. Notes on birds of the Chicago area and its immediate vicinity. Auk 36 (4) :513–524.

———. 1921. Unusual winter occurrences at Chicago. Auk 38 (4) :609–610.

Eisenmann, E. 1973. Thirty-second supplement to the American Ornithologists' Union check-list of North American Birds. Auk 90 (2) :411–419.

———. 1976. Thirty-third supplement to the American Ornithologists' Union check-list of North American Birds. Auk 93 (4) :875–879.

Euspiza. 1876. The American bittern. Ornithologist and Oologist 2 (8) :61–62.

Evermann, B. W. 1889. Wood ibis in Indiana. Auk 6 (2) :186–187.

Faber, R. A., R. W. Risebrough, and H. M. Pratt. 1972. Organochlorines and mercury in common egrets and great blue herons. Environmental Pollution 3 (2) :111–122.

Farwell, E. D. 1919. Bird observations near Chicago. [Privately printed, Chicago.] 188 p.

Fawks, E. 1937. Second-growth hardwood. Bird-Lore 39 (5) :380.

———. 1938. Second-growth hardwood. Bird-Lore 40 (5) :359.

———. 1966*a*. Field notes—March 1966. Audubon Bulletin 137: 3–5.

———. 1966*b*. Field notes—September 1966. Audubon Bulletin 139:22–23.

———. 1967*a*. Field notes. Audubon Bulletin 143:17–21.

———. 1967*b*. Field notes. Audubon Bulletin 144:16–19.

———. 1968. Field notes. Audubon Bulletin 145:14–16.

———. 1970*a*. Field notes. Audubon Bulletin 153:16–19.

———. 1970*b*. Field notes. Audubon Bulletin 155:26–28.

———. 1971*a*. Field notes. Audubon Bulletin 157:27–28.

———. 1971*b*. Field notes. Audubon Bulletin 160:16–17.

———. 1971*c*. Field notes. Audubon Bulletin 161:33–35.

———. 1974. Field notes. Illinois Audubon Bulletin 168:28–29.

———, and P. H. Lobik. 1975. Bird finding in Illinois. Illinois Audubon Society, Downers Grove, Illinois. 98 p.

Ferry, J. F. 1898. Winter observations at Lake Forest. Osprey 2 (6–7) :88–89.

Finley, C. W. 1913. A black-crowned night heronry and need of its protection. Illinois State Academy of Sciences Transactions 6:90.

Fleig, G. M. 1971. The Illinois American Bottoms: summer birding area of Illinois. Audubon Bulletin 157:31–32.

Fogarty, M. J., and W. M. Hetrick. 1973. Summer foods of cattle egrets in north central Florida. Auk 90 (2) :268–280.

Ford, E. R. 1932. Chicago region. Bird-Lore 34 (5) :344–345.

———. 1956. Birds of the Chicago region. Chicago Academy of Sciences Special Publication 12. 117 p.

———, C. C. Sanborn, and C. B. Coursen. 1934. Birds of the Chicago region. Chicago Academy of Sciences Program of Activities 5 (2–3) :17–76.

Franzen, A. J. 1934. Notes from the Chicago district. Auk 51 (3) :402–403.

Freeman, F. J. 1951. A virgin prairie area: Custer Park. Audubon Bulletin 79:2–7.

Galbreath, J. W. 1961. Observations of a nesting colony of egrets and herons. Audubon Bulletin 119:22–23.

———. 1962. Observations of a nesting colony of egrets and herons—report No. 2. Audubon Bulletin 123:9.

Gates, F. C. 1911. Summer bird life in the vicinity of Havana, Illinois in its relation to the prominent plant associations. Wilson Bulletin 23 (1) :1–27.

Gault, B. T. 1901. June and July, bird-life at Glen Ellyn (near Chicago), Illinois. Bird-Lore 3 (3) :102–104.

George, W. G. 1968. Check list of birds of southern Illinois, 1968. Southern Illinois University, Carbondale. Mimeographed. 28 p.

Ginn, W. E. 1954. American egret nesting in Indiana. Indiana Audubon Quarterly 32 (1) :2.

Goelitz, W. A. 1915. Large sets of 1915. Oologist 32 (9) :147–148.

Gower, C. 1932. Field notes. Audubon Bulletin 22:47–48.

Graber, R. 1962. Middlewestern prairie region. Audubon Field Notes 16 (4) :413, 417–420.

———, and W. W. Cochran. 1959. An audio technique for the study of nocturnal migration of birds. Wilson Bulletin 71 (3) :220–236.

———, and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906–1909 and 1956–1958. Illinois Natural History Survey Bulletin 28 (3) :383–528.

Grasett, F. G. 1926. Great blue heron *(Ardea h. herodias)* alighting in water. Auk 43 (3) :367.

Greenberg, R. E., and P. L. Heye. 1971. Insecticide residues in little blue herons. Wilson Bulletin 83 (1) :95–97.

Greer, E. T. 1957. Shore-birds and others in the Davenport region. Iowa Bird Life 27 (4) :97–99.

Greer, R. M. 1966. The brown creeper in Illinois. Audubon Bulletin 140:24–25.

Greer, T. R. 1955. Rambling notes. Audubon Bulletin 95:11–12.

Gross, A. O. 1923. The black-crowned night heron *(Nycticorax nycticorax)* of Sandy Neck. Auk 40 (1) :1–30.

Gylleck, C. 1960. Illinois field notes—1960. Audubon Bulletin 115:14–15.

Haertel, L. S. 1963. Breeding bird populations in relation to the vegetation in Busey Woods, Urbana, Illinois, 1962. M.S. Thesis. University of Illinois. 69 p.

Hamilton, J. L. 1968. Winter survey. December 1st through February 29th. Bluebird 35 (2–3) :3–8.

———. 1969. Spring survey. Bluebird 36 (1) :3–5, 26–28.

Hammerslough, J. S., and R. G. Bjorklund. 1968. Radio tracking of prematurely dislodged nestling herons. Jack-Pine Warbler 46 (2) :57–61.

Hanebrink, E. L., and G. Denton. 1969. Feeding behavior and analysis of regurgitated food collected from the cattle egret *Bubulcus ibis* and the little blue heron *Florida caerulea*. Arkansas Academy of Science Proceedings 23:74–79.

Hankinson, T. H. 1914. Animal life in prairie ponds. Nature Study Review 10 (6) :235–242.

Harford, H. 1959. A flamingo in Missouri. Bluebird 26 (8) :n.p.

Harlan, J. R. 1943. An Iowa nesting colony of the American egret. Iowa Bird Life 13 (4) :59–62.

———. 1945. Egret colony at Sabula abandoned. Iowa Bird Life 15 (3) :48.

Harris, A. T. 1936. Nests found in 1934. Oologist 53 (6) :68–69.

Hess, I. E. 1902. An Illinois heronry. Oologist 19 (10) :145–147.

———. 1910. One hundred breeding birds of an Illinois ten-mile radius. Auk 27 (1) :19–32.

H. F. A. 1889. Wood ibis in Illinois. Oologist 6 (10) :191.

Hickey, J. 1952. Survival studies of banded birds. U.S. Department of the Interior, Fish and Wildlife Service Special Scientific Report (Wildlife) 15. 177 p.

Hicks, L. E. 1934. The wood ibis observed in southern Indiana. Wilson Bulletin 46 (3) :125.

Hill, F. C. 1966. Animal remains from the Stilwell Site, Illinois. Illinois Academy of Sciences Transactions 59 (2) :169–173.

Hodges, J. 1947. The American egret in Iowa. Iowa Academy of Sciences Proceedings 54:317–323.

———. 1950. Recent nesting of the American egret in Iowa. Iowa Academy of Sciences Proceedings 57:461–463.

———. 1951. Nesting colony of the egret in Illinois. Audubon Bulletin 78:6–7.

———. 1953. Recent changes in Davenport bird life. Iowa Bird Life 23 (4) :61–64.

———. 1954. The Burtis H. Wilson journals. Iowa Bird Life 24 (1) :5–8, 24 (2) :34–38.

Hoger, R. B. 1962. Illinois field notes—spring, 1962. Audubon Bulletin 123:3.

———. 1963. Illinois field notes—1962. Audubon Bulletin 125: 15.

———. 1964. Field notes—spring 1964. Audubon Bulletin 130: 18–19.

Houston, C. S. 1967. Recoveries of black-crowned night herons banded in Saskatchewan. Blue Jay 25 (3) :112–113.

Hunter, L. E. 1936. Observations of bird life in Green Bay. Wilson Bulletin 48 (1) :52.

Hurter, J. S. 1881. The harlequin duck and the glossy and wood ibises in southern Illinois. Nuttall Ornithological Club Bulletin 6 (2) :124.

———. 1884. List of birds. Ornithologist and Oologist 9 (8) : 95–97.

Jenkins, L. 1942. A new heron rookery near Clarksville, Mo. Bluebird 9 (9) :59.

Jenni, D. A. 1973. Regional variation in the food of nestling cattle egrets. Auk 90 (4) :821–826.

Johnson, L. G. 1961. Birds seen at the annual meeting. Audubon Bulletin 119:9.

Jones, S. P. 1934. St. Louis region. Bird-Lore 36 (6) :373–374.

———. 1935. St. Louis region. Bird-Lore 37 (5) :380.

———. 1936*a*. St. Louis region. Bird-Lore 38 (4) :312–313.

———. 1936*b*. St. Louis region. Bird-Lore 38 (5) :391–392.

———. 1936*c*. Bird observations in St. Charles Co. [Bluebird] News Letter 3 (8) :68.

———. 1937*a*. St. Louis region. Bird-Lore 39 (4) :322–323.

———. 1937*b*. St. Louis region. Bird-Lore 39 (5) :398–399.

———. 1937*c*. A heronry and marsh trip. Bluebird 4 (6) :71.

———. 1937*d*. St. Louis region. Bird-Lore 39 (6) :475–476.

———. 1938*a*. St. Louis region. Bird-Lore 40 (5) :374–375.

———. 1938*b*. St. Louis region. Bird-Lore 40 (6) :465–466.

———. 1939*a*. St. Louis region. Bird-Lore 41 (3) :190–191.

———. 1939*b*. St. Louis region. Bird-Lore 41 (4) :260.

———. 1940*a*. St. Louis region. Bird-Lore 42 (2) :220–221 (Supplement).

———. 1940*b*. St Louis region. Bird-Lore 42 (3) :309–310 (Supplement).

———. 1940*c*. St. Louis region. Bird-Lore 42 (5) :466–467.

Kahl, M. P. 1963. Mortality of common egrets and other herons. Auk 80 (3) :295–300.

Keller, C. E. 1966. Status of the Ciconiiformes in Indiana. Indiana Audubon Quarterly 44 (3) :56–86.

Kendeigh, S. C., and G. C. West. 1958. Oak-maple forest and edge. Audubon Field Notes 12 (6) :455.

Kennicott, R. 1853–1854. Catalogue of animals observed in Cook County, Illinois. Illinois State Agricultural Society Transactions 1:577–595.

———. 1856. [Untitled.] Boston Society of Natural History Proceedings 5:391.

Kibbe, D. P. 1976. Niagara-Champlain region. American Birds 30 (5) :952–954.

Kleen, V. M. 1974*a*. Middlewestern prairie region. American Birds 28 (1) :58–63.

———. 1974*b*. Middlewestern prairie region. American Birds 28 (3) :645–649.

———. 1974*c*. Middlewestern prairie region. American Birds 28 (4) :807–810.

———. 1974*d*. Middlewestern prairie region. American Birds 28 (5) :908–910.

———. 1974*e*. Field notes. Spring migration. Illinois Audubon Bulletin 170:14–22.

———. 1974–1975. Field notes. Breeding season. Illinois Audubon Bulletin 171:16–18.

———. 1975*a*. Middlewestern prairie region. American Birds 29 (4) :858–862.

———. 1975*b*. Middlewestern prairie region. American Birds 29 (5) :978–982.

———. 1975*c*. Field notes. Spring migration. Illinois Audubon Bulletin 174:28–38.

———. 1975–1976. Field notes. Breeding season. Illinois Audubon Bulletin 175:26–27.

———. 1976*a*. Field notes. Fall migration. Illinois Audubon Bulletin 176:28–36.

———. 1976*b*. Field notes. Spring migration. Illinois Audubon Bulletin 178:25–35.

———. 1976*c*. Field notes. Breeding season. Illinois Audubon Bulletin 179:34–40.

———. 1976*d*. Middlewestern prairie region. American Birds 30 (4) :846–850.

———. 1976–1977. Field notes. Illinois Audubon Bulletin 179: 34–40.

———. 1977*a*. Field notes. Fall migration. Illinois Audubon Bulletin 180:36–46.

———. 1977*b*. Field notes. Spring migration. Illinois Audubon Bulletin 182:38–47.

———, and L. Bush. 1971*a*. Middlewestern prairie region. American Birds 25 (3) :584–588.

———, and ———. 1971*b*. Middlewestern prairie region. American Birds 25 (4) :750–753.

———, and ———. 1971*c*. Middlewestern prairie region. American Birds 25 (5) :862–865.

———, and ———. 1972*a*. Middlewestern prairie region. American Birds 26 (1) :70–73.

———, and ———. 1972*b*. Middlewestern prairie region. American Birds 26 (3) :610–614.

———, and ———. 1972*c*. Middlewestern prairie region. American Birds 26 (4) :765–769.

———, and ———. 1973. Middlewestern prairie region. American Birds 27 (1) :66–70.

Kramer, C. H. 1957. 319. Princeton, Ill. Audubon Field Notes 11 (2) :170.

———. 1962. 402. Princeton, Ill. Audubon Field Notes 16 (2) : 212.

Kumlien, L., and N. Hollister. 1951. The birds of Wisconsin. Revised ed. Wisconsin Society for Ornithology, Madison. 122 p.

Lack, D. 1949. The apparent survival rate of ringed herons. British Birds 42:74–79.

Langdon, S. C. 1940. Evanston bird club hikes. Audubon Bulletin 35:9.

Larsen, J. 1893. Collecting in Chicago. Oologist 10 (2) :42–44.

Levy, S. 1940. Three rare birds in Jackson Park. Audubon Bulletin 33:14.

Lincoln, F. C. 1927. Returns from banded birds. U.S. Department of Agriculture Technical Bulletin 32. 95 p.

ink, G. M. 1940. Many birds are here in winter. Audubon Bulletin 34:7–11.

obik, P. H. 1952. Preservation of Dutchman's Slough. Audubon Bulletin 84:6.

opinot, A. C. 1950. Studies on the great blue heron *Ardea herodias herodias* Linnaeus. Master's Thesis. Southern Illinois University. 46 p.

ucey, P. J. 1916. An opinion of great significance. Audubon Bulletin, Spring:7.

ux, F. E. 1892. A collecting expedition. Oologist 9 (10) :232–233.

ayfield, H. 1948. Middlewestern prairie region. Audubon Field Notes 2 (5) :208–209.

———. 1950*a*. Middlewestern prairie region. Audubon Field Notes 4 (1) :17–19.

———. 1950*b*. Middlewestern prairie region. Audubon Field Notes 4 (5) :278–279.

———. 1951. Middlewestern prairie region. Audubon Field Notes 5 (4) :257–259.

cCarty, W. F. 1928. A central Illinois night-heronry. Audubon Bulletin 19:57–59.

cCaskie, G. 1973. Southern Pacific coast region. American Birds 27 (5) :917–920.

cMillen, H. E. 1964. Gleanings from our field records. Audubon Bulletin 130:25–26.

cVaugh, W., Jr. 1972. The development of four North American herons. Living Bird 11th Annual:155–173. Cornell University, Laboratory of Ornithology, Ithaca, New York.

———. 1975. The development of four North American herons, II. Living Bird 14th Annual:163–183. Cornell University, Laboratory of Ornithology, Ithaca, New York.

eyerriecks, A. J. 1960. Comparative breeding behavior of four species of North American herons. Nuttall Ornithological Club Publication 2. Cambridge, Massachusetts. 158 p. + 15 plates.

iller, R. J. 1955. Bird populations on Illinois prairie farmland. Master's Thesis. University of Illinois. 86 p.

iller, R. R. 1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. U.S. Department of the Interior, Fish and Wildlife Service Fishery Bulletin 173 (Vol. 60) :371–392.

ills, H. B., W. C. Starrett, and F. C. Bellrose. 1966. Man's effect on the fish and wildlife of the Illinois River. Illinois Natural History Survey Biological Notes 57. 23 p.

ousley, H. 1939. Home life of the American bittern. Wilson Bulletin 51 (2) :83–85.

umford, R. E. 1959. Middlewestern prairie region. Audubon Field Notes 13 (5) :433–434.

———. 1960*a*. Middlewestern prairie region. Audubon Field Notes 14 (1) :38–41.

———. 1960*b*. Middlewestern prairie region. Audubon Field Notes 14 (3) :312–314.

———. 1960*c*. Middlewestern prairie region. Audubon Field Notes 14 (5) :452–454.

———. 1961*a*. Middlewestern prairie region. Audubon Field Notes 15 (3) :332–334.

———. 1961*b*. Middlewestern prairie region. Audubon Field Notes 15 (4) :413–416.

———. 1961*c*. Middlewestern prairie region. Audubon Field Notes 15 (5) :471–472.

urchison, A. C. 1892. A quawk town. Oologist 9 (7) :177–178.

———. 1893*a*. Distribution of the black-crowned night heron in Illinois. Ornithologist and Oologist 18 (6) :82–85.

———. 1893*b*. The American and least bitterns in Henry County, Illinois. Oologist 10 (9) :247–249.

———. 1896. The American bittern. Nidologist 3 (10–11) :118–119.

usselman, T. E. 1916–1917. Unusual birds along the Mississippi River near Quincy. Audubon Bulletin, Winter:39–40.

———. 1921. The birds of Illinois. Illinois State Historical Society Journal 14. 75 p.

———. 1926. Quincy district, the eagles at Warsaw. Audubon Bulletin 17:41–42.

———. 1932*a*. The 1931 season at Quincy. Audubon Bulletin 22:48–51.

———. 1932*b*. Egrets at Quincy, Ill. Auk 49 (1) :78–79.

———. 1933. Quincy nature diary for 1932. Audubon Bulletin 23:50–54.

———. 1934–1935. 1934 nature diary. Audubon Bulletin 24–25:27–35.

———. 1937. 1936 nature diary. Audubon Bulletin 27:36–44.

———. 1968*a*. Magnificent birds winter on the Mississippi. Purple Martin News 3 (2) :20.

———. 1968*b*. Chuck-will's widow and wood ibis in central Illinois. Wilson Bulletin 80 (2) :230.

Nelson, E. W. 1876. Additions to the avifauna of Illinois with notes on other species of Illinois birds. Nuttall Ornithological Club Bulletin 1 (2) :39–44.

———. 1876–1877. Birds of north-eastern Illinois. Essex Institute Bulletin 8 (9–12) :90–155.

———. 1877. Notes upon birds observed in southern Illinois between July 17 and September 4, 1875. Essex Institute Bulletin 9:32–65.

Nice, M. M. 1952. Breeding birds of Jackson Park. Audubon Bulletin 82:3–7.

Nolan, V. 1952. Middlewestern prairie region. Audubon Field Notes 6 (5) :284–285.

———. 1953*a*. Middlewestern prairie region. Audubon Field Notes 7 (3) :215–216.

———. 1953*b*. Middlewestern prairie region. Audubon Field Notes 7 (4) :275–276.

———. 1953*c*. Middlewestern prairie region. Audubon Field Notes 7 (5) :310–312.

———. 1954*a*. Middlewestern prairie region. Audubon Field Notes 8 (4) :315.

———. 1954*b*. Middlewestern prairie region. Audubon Field Notes 8 (5) :347–349.

———. 1955*a*. Middlewestern prairie region. Audubon Field Notes 9 (4) :333–335.

———. 1955*b*. Middlewestern prairie region. Audubon Field Notes 9 (5) :380–382.

———. 1956. Middlewestern prairie region. Audubon Field Notes 10 (4) :336–338.

———. 1957. Middlewestern prairie region. Audubon Field Notes 11 (5) :407–409.

———. 1958*a*. Middlewestern prairie region. Audubon Field Notes 12 (3) :282–284.

———. 1958*b*. Middlewestern prairie region. Audubon Field Notes 12 (5) :415–417.

Oberholser, H. C. 1912. A revision of the subspecies of the green heron (*Butorides virescens* Linnaeus). U.S. National Museum Proceedings 42 (1916) :529–577.

———. 1913. A revision of the forms of the great blue heron (*Ardea herodias* Linnaeus). U.S. National Museum Proceedings 43 (1939) :531–559.

Olmstead, R. E. 1906. The little green heron. Bird-Lore 8 (1) : 12–13.

Owen, D. F. 1959–1960. The nesting success of the heron *Ardea cinerea* in relation to the availability of food. Zoological Society of London Proceedings 133:597–617.

Palmer, R. S., ed. 1962. Handbook of North American birds. Vol. I. Yale University Press, New Haven and London. 567 p.

Parmalee, P. 1957. Vertebrate remains from the Cahokia site, Illinois. Illinois State Academy of Science Transactions 50: 235–242.

———. 1959. Animal remains from the Modoc rock shelter site, Randolph County, Illinois. Illinois State Museum Report of Investigations 8:61–65.

———. 1962*a*. Additional faunal records from the Kingston Lake site, Illinois. Illinois Academy of Science Transactions 55 (1) :6–12.

———. 1962*b*. The faunal complex of the Fisher site, Illinois. American Midland Naturalist 68 (2) :399–408.

———. 1964. Vertebrate remains from an historic archaeological site in Rock Island County, Illinois. Illinois Academy of Science Transactions 57 (3) :167–174.

———. 1969. Animal remains from the archaic Riverton, Swan Island and Robeson Hill sites, Illinois. Illinois State Museum Reports of Investigations 13:139–144.

———, A. A. Paloumpis, and N. Wilson. 1972. Animals utilized by woodland peoples occupying the Apple Creek site, Illinois. Illinois State Museum Reports of Investigations 23:1–62.

———, and G. Perino. 1970. A prehistoric archaeological record of the roseate spoonbill in Illinois. Illinois Academy of Science Transactions 63 (3) :254–258.

Petersen, P. C. 1959. TV tower mortality in western Illinois. Audubon Bulletin 112:14–15.

———. 1963. Middlewestern prairie region. Audubon Field Notes 17 (5) :463–465.

———. 1964. Middlewestern prairie region. Audubon Field Notes 18 (1) :42–44.

———. 1966*a*. Middlewestern prairie region. Audubon Field Notes 20 (1) :53–55.

———. 1966*b*. Middlewestern prairie region. Audubon Field Notes 20 (5) :574–575.

———. 1967*a*. Middlewestern prairie region. Audubon Field Notes 21 (1) :44–45.

———. 1967*b*. Middlewestern prairie region. Audubon Field Notes 21 (4) :513–514.

———. 1968*a*. Middlewestern prairie region. Audubon Field Notes 22 (4) :531–533.

———. 1968*b*. Middlewestern prairie region. Audubon Field Notes 22 (5) :612–614.

———. 1969. Middlewestern prairie region. Audubon Field Notes 23 (4) :596–597.

———. 1970. Middlewestern prairie region. Audubon Field Notes 24 (1) :54–55.

———. 1971. Middlewestern prairie region. American Birds 25 (1) :64–66.

———, and N. Ward. 1966. An Illinois heronry. Audubon Bulletin 139:20.

Peterson, C. T. 1965. An unusual colony of little blue herons. Wilson Bulletin 77 (2) :192–193.

Pitelka, F. 1937. Notes from the Illinois Audubon Society. Chicago Academy of Sciences Program of Activities 8 (3) :34–38.

Princen, L. H. 1968. A listing of unusual bird sightings in central Illinois during 1967. Peoria Academy of Science Proceedings 1:46–49.

———. 1969. Unusual bird sightings in central Illinois during 1968. Peoria Academy of Science Proceedings 2:20–23.

———. 1975. Unusual bird sightings in central Illinois during 1974. Peoria Academy of Science Proceedings 8:35–40.

Reed, C. A. 1965. North American bird eggs. Revised ed. Dover Publications, Inc., N.Y. 372 p.

Ridgway, R. 1874. The lower Wabash valley considered in relation to faunal districts of the eastern region of North America; with a synopsis of its avian fauna. Boston Society of Natural History Proceedings 16:304–332.

———. 1878. Notes on birds observed at Mount Carmel, southern Illinois, in the spring of 1878. Nuttall Ornithological Club Bulletin 3:162–166.

———. 1880. On six species of birds new to the fauna of Illinois, with notes on other rare Illinois birds. Nuttall Ornithological Club Bulletin 5 (1) :30–32.

———. 1881. A revised catalogue of the birds ascertained to occur in Illinois. Illinois State Laboratory of Natural History Bulletin 1 (4) :163–208.

———. 1882. Notes on some of the birds observed near Wheatland, Knox Co., Indiana in the spring of 1881. Nuttall Ornithological Club Bulletin 7 (1) :15–23.

———. 1887. List of birds found breeding within corporate limits of Mt. Carmel, Illinois. Ridgway Ornithological Club Bulletin 2:26–35.

———. 1895. The ornithology of Illinois. Vol. 2. Illinois State Laboratory of Natural History. Reprinted 1913. Pantagraph Printing and Stationery Company, Bloomington, Ill. 282 p. + 33 plates.

———. 1925. The birds of 'Larchmound'—a resumé. Bird-Lore 27 (5) :305–309.

Ries, D. T., and F. G. Werner. 1946. Checklist of the birds of Starved Rock State Park and surrounding territory. Illinois State Academy of Science Transactions 39:135–142.

Riis, P. B. 1921. Notes from the field, revised to March 15, 1921. Audubon Bulletin, Spring: 40–41.

Robertson, W., Jr. 1941*a*. 9. Swampy prairie. Audubon Magazine 43 (5) :485.

———. 1941*b*. 33. Cut-over upland forest with pond. Audubon Magazine 43 (5) :496–497.

———. 1942*a*. 5. Swampy prairie. Audubon Magazine 44 (5) : 18–19 (Supplement) .

———. 1942*b*. 22. Cut-over upland oak-hickory forest with pond. Audubon Magazine 44 (5) :27 (Supplement) .

———. 1944*a*. 5. Swampy prairie. Audubon Magazine 46 (5) : 16 (Supplement) .

———. 1944*b*. 14. Upland oak-hickory forest with pond. Audubon Magazine 46 (5) :19 (Supplement) .

Ryder, R. A. 1967. Distribution, migration and mortality of the white-faced ibis *(Plegadis chihi)* in North America. Bird-Banding 38 (4) :257–277.

Sanborn, C. C. 1921. Chicago region. Bird-Lore 23 (4) :203–204.

———. 1934*a*. Chicago region. Bird-Lore 36 (3) :185.

———. 1934*b*. Chicago region. Bird-Lore 36 (4) :246–247.

———. 1935*a*. Chicago region. Bird-Lore 37 (3) :225–226.

———. 1935*b*. Chicago region. Bird-Lore 37 (4) :292–293.

———, and W. A. Goelitz. 1915. A two-year nesting record in Lake County, Illinois. Wilson Bulletin 27 (4) :434–448.

Schulze, P. 1966. Bird escapees cause excitement. Audubon Bulletin 139:21.

Segal, S. 1960. Bird tragedy at the Dunes. Indiana Audubon Quarterly 38 (2) :23–25.

Shoop, C. E. 1931. Trematodes infesting the neck of a great blue heron. Wilson Bulletin 43 (2) :145.

Short, W. 1938. St. Louis, Mo. Bluebird 5 (10) :97–98.

———. 1939. St. Louis notes. Bluebird 6 (6) :50–51.

———. 1942. St. Louis bird club notes. Bluebird 9 (9) :60–61.

Silloway, P. M. 1906. A novice's notebook—No. 6. Oologist 23 (10) :155–156.

Skaar, P. D. 1951. Posey County expedition. Indiana Audubon Quarterly 29 (1) :13–14.

Smith, E. T. 1941. Chicago region. Audubon Magazine 43 (5) : 472–473.

———. 1942*a*. Chicago region. Audubon Magazine 44 (3) :8.

———. 1942*b*. Chicago region. Audubon Magazine 44 (6) :8–9 (Supplement) .

———, and P. A. DuMont. 1944. Middlewestern region. Audubon Magazine 46 (4) :104–106 (Supplement) .

Smith, F. 1930. Records of spring migration of birds at Urbana, Illinois, 1903–1922. Illinois Natural History Survey Bulletin 19 (2) :105–117.

Smith, H. R., and P. W. Parmalee. 1955. A distributional check list of the birds of Illinois. Illinois State Museum Popular Science Series 4. 62 p.

Snyder, D., C. Bonney, and W. B. Robertson. 1948. Twelfth breeding-bird census. 15. Deciduous flood-plain forest. Audubon Field Notes 2 (6) :237.

Stewart, C. A. 1949. Observations on the American egret in Iowa. Iowa Bird Life 19 (1) :2–5.

Stout, E. 1934. The bittern's courtship dance. Chicago Academy of Sciences Program of Activities 5 (4) :90.

Strode, W. S. 1917. Crane town destroyed. Illinois State Academy of Science Transactions 10:330–332.

Strong, R. M. 1932. The McGinnis Slough. Chicago Academy of Sciences Program of Activities 3 (2) :n.p.

Thompson, M. 1960. 1959 nesting report. Audubon Bulletin 115:7–13.

U.S. Department of Commerce, Environmental Data Service. 1975–1976. Climatological data. Illinois. November 1975. 80 (11) :2–3.

Weeks, H. P. 1976. Breeding of the yellow-crowned night heron in Indiana. Indiana Audubon Quarterly 54 ((3) :83–86.

Weller, M. W. 1961. Breeding biology of the least bittern. Wilson Bulletin 73 (1) :11–35.

White, H. G. 1890. Geographical variation in eggs. Ornithologist and Oologist 15 (1) :1–4.

Widmann, O. 1880. Notes on the birds of St. Louis, Mo. Nuttall Ornithological Club Bulletin 5 (3) :191–192.

———. 1907. A preliminary catalog of the birds of Missouri. Academy of Science of St. Louis Transactions 17 (1) . 288 p.

Wilhelm, G. 1954. St. Louis area 1953. Bluebird 21 (3) :n.p.

Williams, R. J. 1957. The great blue heron colonies of Wisconsin. Passenger Pigeon 19 (2) :51–66.

Woodruff, F. M. 1907. The birds of the Chicago area. Chicago Academy of Sciences Natural History Survey Bulletin 6. 221 p.

Woodruff, F. L. 1908. The reappearance of the American egret near Chicago. By the Wayside 11 (1) :1, 3.

Work, R. 1934–1935. Barrington bird club. Audubon Bulletin 24–25:70–71.

Wrischnik, L. 1973. Herons and egrets—Always forced to move? Illinois Audubon Bulletin 166:26.

———. 1975–1976. Rosalee Comment Heron Sanctuary. 1975 census. Illinois Audubon Bulletin 175:24.

Yeager, L. E. 1949. Effects of permanent flooding in a river-bottom timber area. Illinois Natural History Survey Bulletin 25 (2) :33–65.

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Biology

ILLINOIS BIRDS: Sylviidae

Jean W. Graber, Richard R. Graber, Ethelyn L. Kirk

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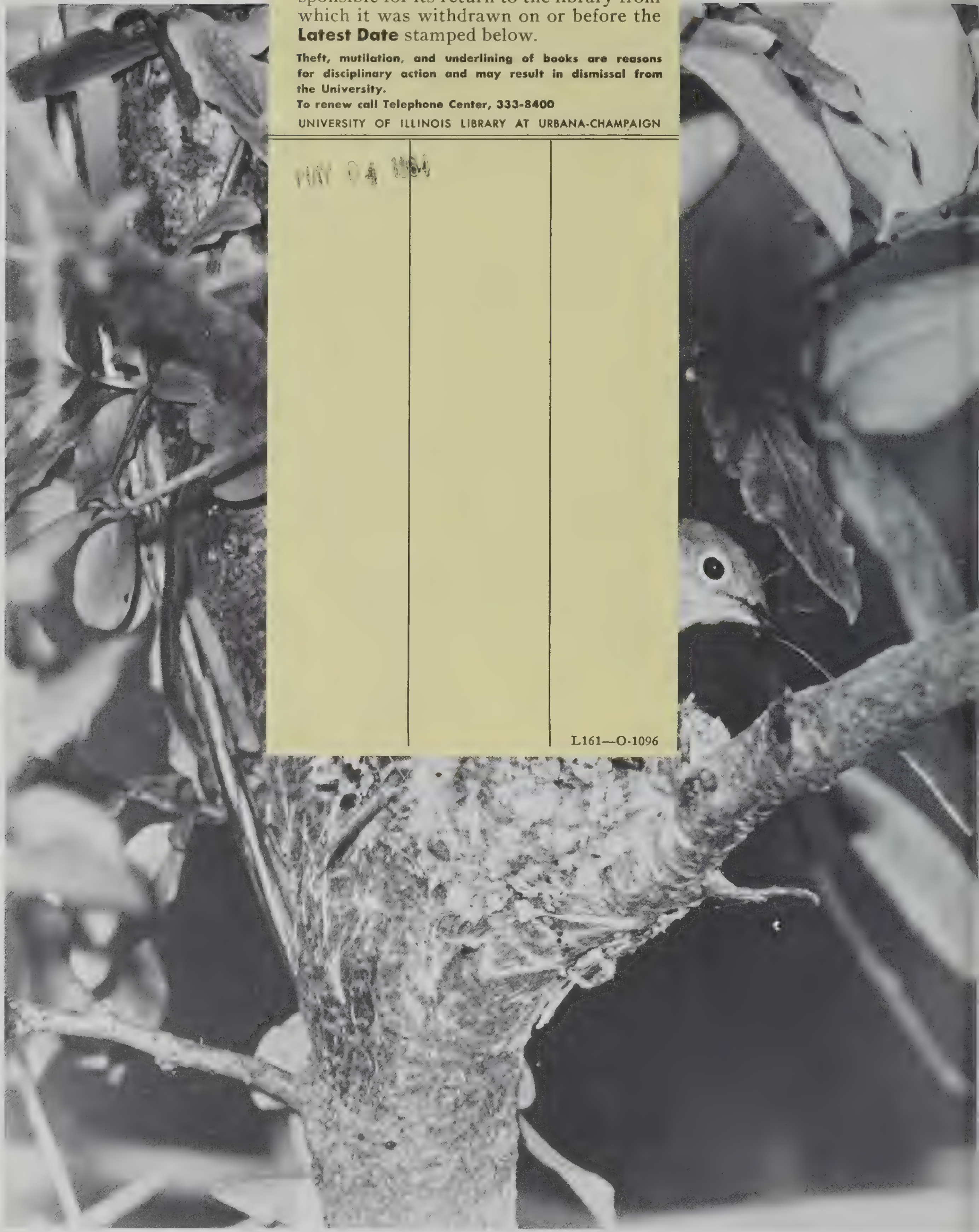

Fig. 1.—Female blue-gray gnatcatcher working on its nest in Pope county, 29 April 1973.

ILLINOIS BIRDS: Sylviidae

Jean W. Graber, Richard R. Graber, and Ethelyn L. Kirk

This is the eighth in a series of papers (e.g., Graber et al. 1978) designed especially to summarize the population data on Illinois birds. Our policies and procedures in collecting, analyzing, and presenting data have been outlined in the introductions of the papers, different aspects of the project being covered in each paper.

Anyone who attempts to census populations of birds is inevitably confronted with a problem that we might refer to as the "dilution factor," of which two important types warrant mention: (1) habitat-related dilution and (2) species-related dilution. The problem affects population measurements of all species, but may have some special significance to the sylviids because of their small size and relatively faint voices. The problem of dilution can perhaps best be explained by example, and concerns the difference in the detectability of one golden-crowned kinglet (an arboreal species) in one tree in the middle of an open field versus the dectectability of one kinglet in a forest (i.e., one tree versus several hundred). The bird is much more likely to be detected in the first instance. In Illinois this problem becomes particularly noteworthy between east-central and northeastern Illinois (areas with relatively few trees) on the one hand, and western and southern Illinois (areas with many trees) on the other. The consistently high counts of transients in east-central Illinois and the low counts for southern Illinois may have as much to do with the dilution factor as with actual population size.

Complicating the problem of habitat-related dilution is that of species-related dilution. It is probably easier to detect a kinglet that is by itself than to identify one in a large flock of other transients—say 200 birds of several species. In a sense each bird is competing for the observer's attention; the time required to identify one specimen reduces the time available for all the rest. Detectability of birds varies from species to species, its effect on a census is difficult to assess objectively, and thus, it is largely ignored.

An important question of concern to the conservation of wild populations is, what constitutes essential habitat? For most, if not all, populations the answer is unknown. Our few observations on the life cycle of the gnatcatcher relate to the species in upland habitat, where populations are relatively low and where nesting success seemed poor. Could the Illinois populations of this species sustain themselves over the long run if all the bottomland habitat were destroyed? We do not know the answer, but the question is one that needs to be asked (and researched) about all species and all habitats. Ecological breadth in a population seems all to the good and may be essential. Because of the vagaries of weather and the unknown actions of other populations, the habitat that sustains a species in one year may not carry it at all in another. It is *not* enough just to know that a population occupies a particular habitat. Beyond that it is essential to know what that habitat contributes to the population and its survival *from year to year*. Such knowledge will come only from very *detailed, long-term* ecological investigations of every habitat and the populations that each supports. The importance of long-term studies is indicated in the dramatic change that occurred in the winter populations of kinglets between 1977 and 1978. How different our impression of the population of these species would be if we had only the 1978 data.

In the preparation of this paper we have benefitted particularly from contributions of data from Marilyn Campbell and her associates on the staff of the Vermilion County Conservation District and their many cooperators; H. David Bohlen of the Illinois State Museum; Vernon Kleen of the Illinois Department of Conservation; Mrs. William Carroll of Woodstock; and Bowie Hannah of Dix.

Though we do not usually mention it, the consistently fine help provided virtually every day in one way or another by staff at every level of the Illinois Natural History Survey is deeply appreciated and, more to the point, essential.

BLUE-GRAY GNATCATCHER
(Polioptila caerulea)

(Cover, Fig. 1 and 2)

Spring Migration

The blue-gray gnatcatcher usually arrives in southern Illinois in late March or early April. This arrival is surprisingly early for a small, insectivorous bird, and is before the last frosts in the area. The

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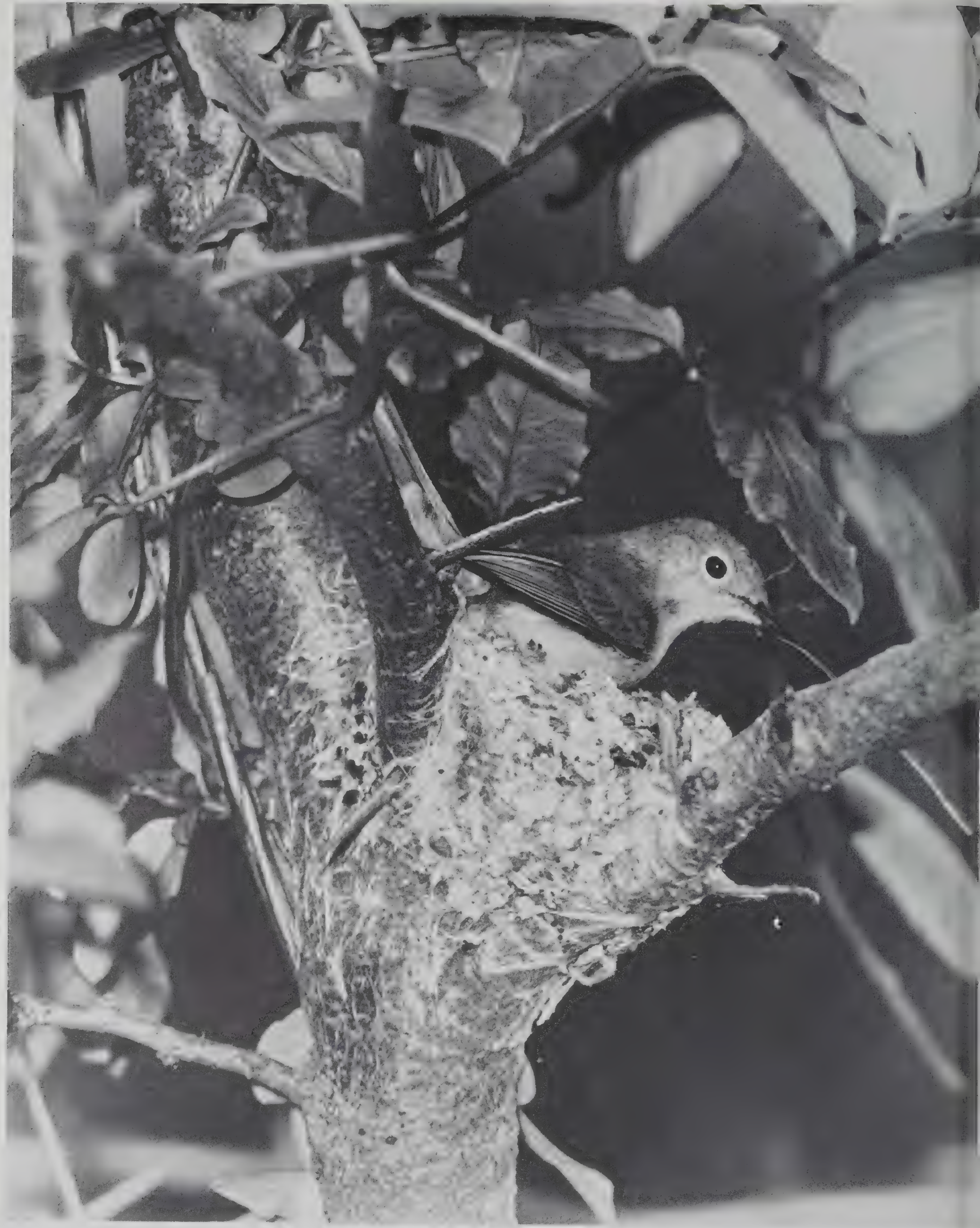
This paper is published by authority of the State of Illinois. It is a contribution from the Section of Wildlife Research of the Illinois Natural History Survey. Dr. Jean W. Graber and Dr. Richard R. Graber are Wildlife Specialists, and the late Miss Ethelyn L. Kirk served as a Technical Assistant in the Section of Wildlife Research.



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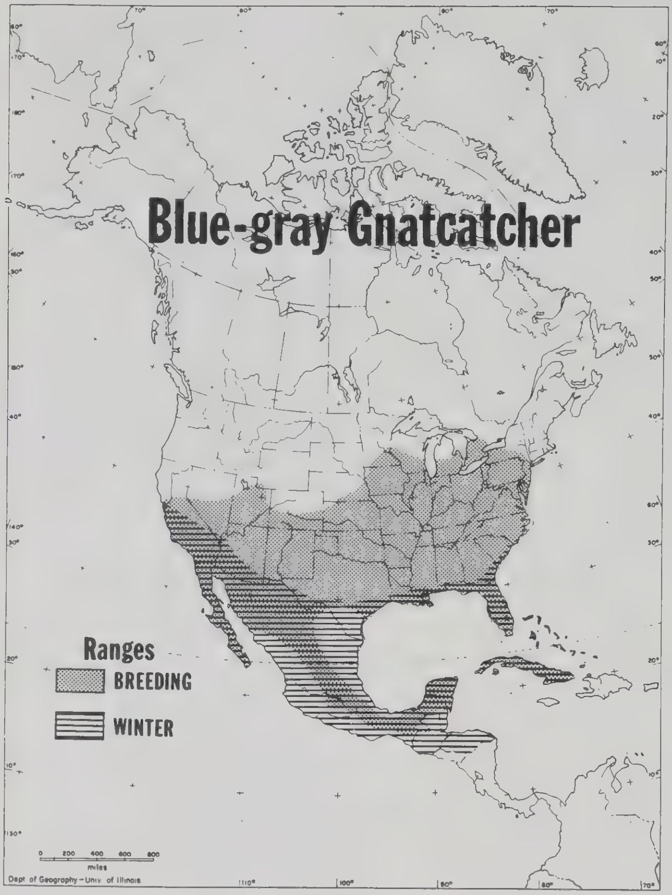

Fig. 2.—General distribution of the blue-gray gnatcatcher.

earliest arrival reported for southern Illinois is 15 March (Kleen unpublished 1977). The bulk of the migrants in southern Illinois are seen from mid-April to early May (Fig. 3). In central Illinois the earliest arrival thus far reported is 30 March (Smith 1930), and the bulk of the migration occurs from about 28 April to 12 May.

A published record for the gnatcatcher on 7 March in the Chicago area (Fawks 1965) is amazing if correct. More realistic as an early arrival date for northern Illinois is 2 April at Rockford (L. G. Johnson unpublished 1959), and gnatcatchers are not usually seen in the north much before mid-April, with largest numbers occurring in May.

The presence of breeding birds makes it difficult to determine precisely the end of the spring migration. William Dreuth found the gnatcatcher no later than 26 May in Lincoln Park, where the species was not known to nest (Clark & Nice 1950).

Distribution

The general distribution of the blue-gray gnatcatcher is shown in Fig. 2. In Illinois gnatcatchers are to be expected in every county, but definite nesting records are still lacking for many (Fig. 4). In addition to the localities shown, there are recent breeding records for Pike County and the Chicago area (Kleen unpublished 1977).

Nesting Habitats and Populations

Brief descriptions of gnatcatcher habitat appear in the Illinois literature. Nelson (1876–1877) and Woodruff (1907) speculated that the lack of "heavy timber" accounted for the scarcity of gnatcatchers in the Chicago area. Greer (1923) said that gnatcatchers invariably chose to nest in willows near water in the Aledo area, and Gates (1911) listed the species as a dominant in bottomland woods near Havana. Hess (1910) wrote that in the Philo area gnatcatchers were absent from the upland but occurred in low, wet woods along the Salt Fork. Near Berlin, Robertson (1944) found that gnatcatchers were largely confined to climax woods. In southern Illinois, Nelson (1877) found gnatcatchers common in the tall oaks of the bottomland near Mt. Carmel. Ridgway (1889) considered the habitat to be high, open woods, often along streams. A strikingly different habitat was scrub oak near Beach, where Sanborn (1922) found a family of gnatcatchers.

The primary breeding habitat for the blue-gray gnatcatcher in Illinois is riparian woods, where this bird usually occupies the first level above the floodplain. June populations of the gnatcatcher in all bottomland woods that we censused in southern Illinois, 1973–1978, averaged 18.6 birds per 40.5 ha, whereas those in upland woods averaged 7.6 birds per 40.5 ha (Table 1). Even in upland areas, the gnatcatcher is most often found along waterways. That bottomland woods is primary gnatcatcher habitat is also shown during population declines, when the decrease is most evident in upland (less preferred) habitat. For example, our breeding bird census for 1978 (a year in which bird populations were generally low) show that the population of gnatcatchers in bottomland forests in southern Illinois remained nearly the same as for the previous years (1973–1977), whereas the population in upland forests dropped to half the average for that period (Table 1). Gnatcatcher populations are generally more variable in upland than in bottomland habitat (Table 2).

Gnatcatchers have been recorded during the breeding season in southern Illinois towns (Ridgway 1887), but densities in residential habitat are very low (Table 1).

No characteristic of the vegetation (species composition, stem density, basal area) that we measured in our forest study areas in southern Illinois showed correlation with gnatcatcher populations.

Gnatcatcher populations in central and northern Illinois are now generally low, but available counts indicate that they were higher early in this century (Gault 1922, Clark & Nice 1950, Fig. 3). Gates (1911) considered the gnatcatcher to be a dominant of bottomland woods along the Illinois River, where Frank Bellrose (unpublished) has found them uncommon since 1938. The spring bird count (Kleen 1973, 1974, 1975*a*, 1976, 1977) indicates that the gnatcatcher population in early May (which includes both transient

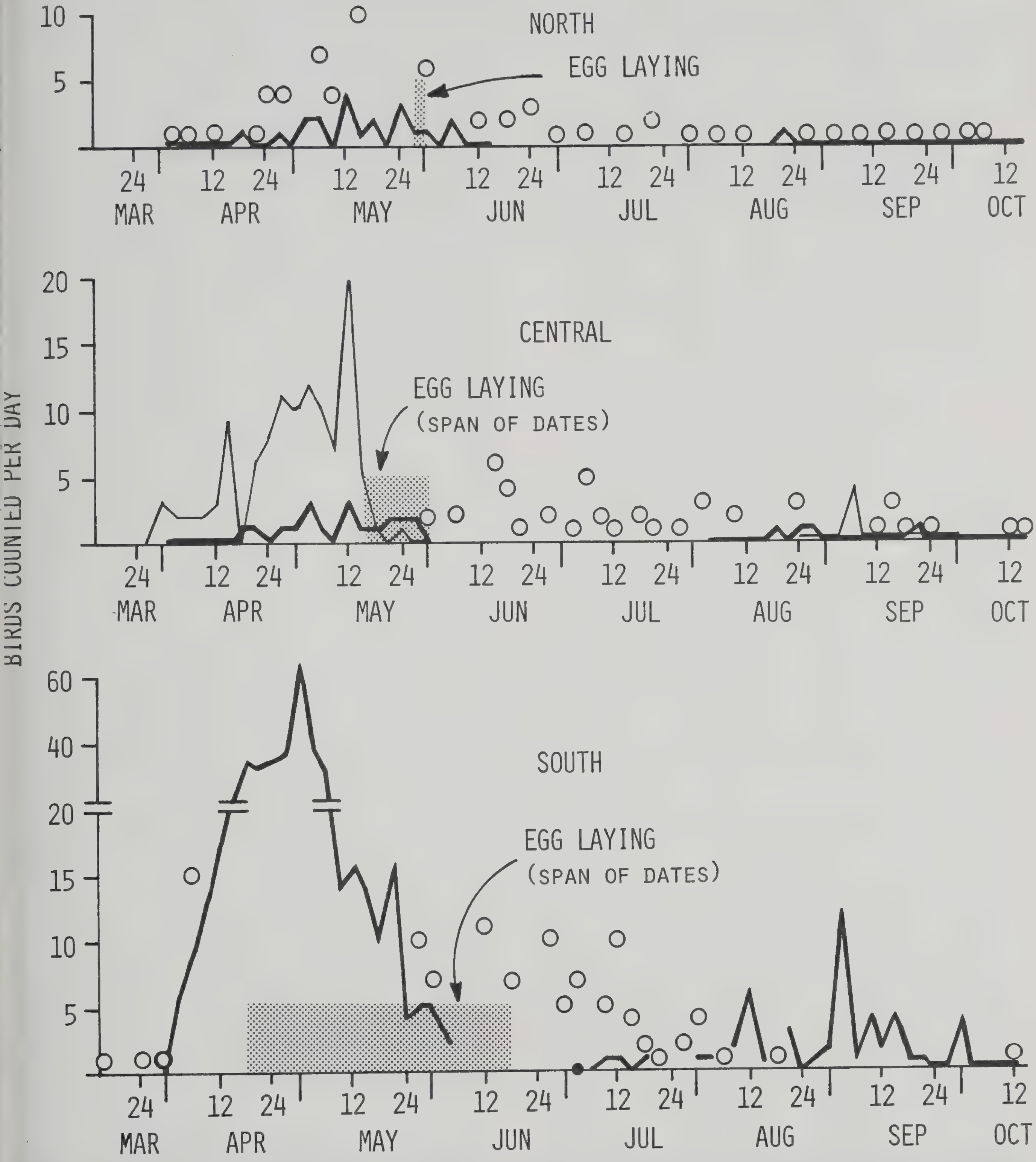

Fig. 3.—Egg-laying and migration seasons of the blue-gray gnatcatcher in different regions of Illinois (see Fig. 10 for regions). Spring and fall graph lines (heavy lines) show the highest daily count of each 4 days (1967–1970). Lighter line (central region) shows the highest daily counts of each 4 days made by F. Smith and his students, 1903–1925. Hollow circles represent counts made in other years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded.

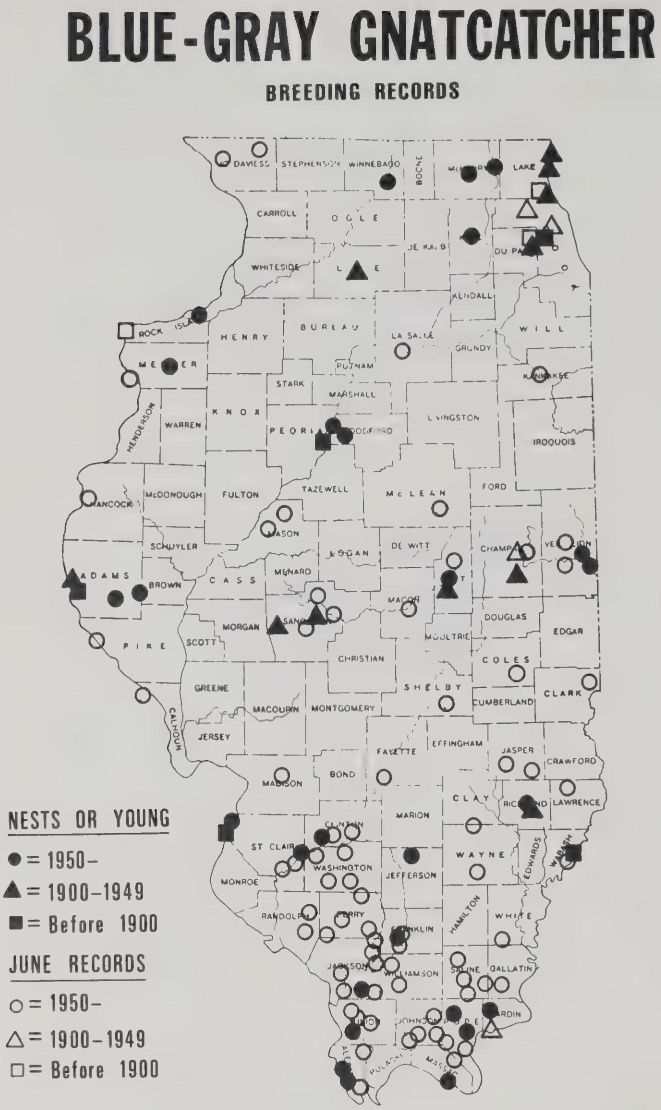

Fig. 4.—Breeding records of the blue-gray gnatcatcher in Illinois.

and breeding birds) is low in northern and central Illinois (0–0.4 bird per party hour). At about the latitude of Coles County, the number increases to about 1 gnatcatcher per party hour, and in the extreme south (Pope County) counts have been as high as 5 per party hour.

The population density of gnatcatchers may be influenced by the number of cowbirds *(Molothrus ater)* present. In our forest study areas in southern Illinois, the density of the gnatcatcher populations remained under 15 per 40.5 ha when the ratio of cowbirds to gnatcatchers was 1:1. In one bottomland woods, no gnatcatchers were found in a year when the cowbird population was high (33 cowbirds per 40.5 ha).

The gnatcatcher spends much of its time in the middle and upper canopy. J. Graber observed a gnatcatcher bathing on the dew on oak leaves about 30 feet above the ground. Trees chosen for nest sites (Table 3) reflect the habitat to some extent, but our list is biased in that most of the records represent a single tract of upland forest in Pope County. Greer (1923) said that near Aledo willows were invariably chosen as nest trees, often near water.

The height of 5 nests in northern Illinois ranged from 6 to 9 m (mean: 7.9 m); 13 nests in central Illinois were 6–15 m high (mean: 10.4 m); and 59 nests in southern Illinois ranged from 1.5 to 19.8 m (mean: 8.0 m), with a definite mode at 6–10 m. The nest may be placed in a crotch, as in Fig 1, or saddled on a horizontal limb.

Nesting Cycle

Ridgway (1889) described the gnatcatcher's song as a weak imitation of the song of the catbird *(Dumetella carolinensis)*, with considerable power but little sweetness. The high pitched song also seems to lack a consistent or distinctive pattern. The common call, a wheezy, squeaky "Zeee-eef" carries a surprising distance.

In northern Illinois, Greer (1923) found that nest building began about a week after arrival of the pair. Nest building begins in southern Illinois at least by 14 April. J. Graber watched a pair choosing a nest site. The female examined four crotches in a red elm by sitting in them and turning her head about and shaping herself into the crotch. The male followed the female about, singing softly. The following day the pair had started building in one of the crotches that the female had examined. Nest building in southern Illinois has been described by Hunter (1969).

We observed that nest materials were gathered within about 1–30 m of the nest sites, but once we saw a pair going 90 m, apparently outside their usual territorial limits and at the edge of the habitat, to gather spider web. Both members of a pair usually work at building the nest, but in one instance a female built the nest by herself in about 3 days. The male followed her about and chased away a neighboring male whenever it approached her. Twice we watched pairs building for a short period (40 minutes). One pair made 27 trips (the female 20, the male 7) with nesting material; another pair made 19 trips in that time (the male 11, the female 8). The female of the latter pair spent considerable time putting materials into the nest and shaping it with her body. Several times her mate (Fig. 5) gave her material he had gathered. Each bird sat in the nest (separately) and extended its head over the side, attaching spider web over the outside of the nest and to the limbs holding it. Gnatcatchers chased away other species of birds (catbird; yellow-breasted chat, *Icteria virens;* and female cardinal, *Cardinalis cardinalis)* which approached their nest while they were building.

The nest (cover, Fig. 1 and 6) is a deep cup made of various soft plant materials held together and at-

TABLE 1.—Breeding populations of blue-gray gnatcatchers in various Illinois habitats.

Habitat	Hectares	Birds per 40.5 ha[a]	Years	Type of Census	Region or County	Reference
Urban residential	139	0.3	1976–1977	Strip	South	This paper
Oak-maple forest	22	3.6	1928	Map	Champaign (C)[b]	Kendeigh 1944
Oak-maple forest	22	0.0	1924–1977 (except 1928)	Map	Champaign (C)	Kendeigh 1948*b*, Kendeigh & Edgington 1977
Oak-hickory-maple forest	13	6.3	1976	Map	McLean (C)	Birkenholz 1977
Oak-hickory-ash forest	16	6.0	1966–1971	Map	Vermilion (C)	Willson 1974
Bottomland (floodplain) forest	1.7	26.0	1966	Map	Vermilion (C)	Karr 1968
Bottomland (floodplain) forest	10	16.0	1966–1971	Map	Piatt (C)	Willson 1974
Bottomland woods	94	0.2	1978	Strip	Central	This paper
Grazed bottomland woods	21	3.8	1955	Map	Macon (C)	Chaniot & Kirby 1955*b*
Virgin floodplain forest	31	2.7	1948	Map	Sangamon (C)	Snyder et al. 1948
Mature bottomland forest	957	0–59 (avg 18.6)	1973–1978	Strip	South	This paper
Swamp and thicket	5	15.4	1950	Map	Jackson (S)	Brewer & Hardy 1950
Upland deciduous forest	8	0–10 (avg 3.3)	1914–1916	Nest	Rock Island (N)	J. J. Schafer unpublished
Upland deciduous forest	22	0–5 (avg 1.1)	1917–1923	Nest	Rock Island (N)	J. J. Schafer unpublished
Upland oak-hickory forest	23	3.6	1944	Map	Sangamon (C)	Robertson 1944
Upland forest	13	6.0	1966–1971	Map	Piatt (C)	Willson 1974
Upland forest	43	0.0	1978	Strip	Central	This paper
Mature upland forest	511	2–27 (avg 7.6)	1974–1978	Strip	South	This paper
Upland deciduous forest	6	39.5	1976	Map	Jackson (S)	Morrison & Peterjohn 1977
Forest (all types, including edge)	72	0–4 (avg 2.1)	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	87	1–3 (avg 2.3)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	138	6–12 (avg 8.9)	1957–1958	Strip	South	Graber & Graber 1963
Shrub	52	0–3 (avg 1.5)	1957–1958	Strip	South	Graber & Graber 1963

[a] All figures were converted to birds per 40.5 ha (number of territorial males or nests × 2).

[b] N refers to the northern region of Illinois, C to the central, and S to the southern region, as shown on winter distribution maps, e.g., Fig. 10.

TABLE 2.—Annual variation in breeding gnatcatcher populations in bottomland and upland forests in southern Illinois.

Year	Gnatcatchers per 40.5 ha	
	Bottomland Forest	Upland Forest
1974	15.5	6.1
1975	13.4	14.0
1976	19.6	4.9
1977	22.5	8.9
1978	17.8	3.7
Mean	*17.8*	*7.5*
Standard deviation	*3.5*	*4.1*
Coefficient of variation	*0.199*	*0.544*

tached to the substrate with spider web. Inside it is often lined with hair. The hair lining of a nest in Pope County appeared to be from an oppossum, *Didelphis virginiana.* Materials used in the feltlike walls of nests included small pieces of cedar, river birch, and other bark; fine grass stems; small rootlets; cottony fibers from milkweed; skeletonized leaves; and the hair found around the bases of sycamore seeds (nutlets). A consistent feature of the nest is its outside covering of gray and glaucous lichens, which tends to camouflage the nest, making it look like a knot on a limb (Ridgway 1889). One of the lichens has been identified as *Parmelia caperata* by J. L. Crane of the Illinois Natural History Survey. Measurements of two nests from Pope County were: inside diameter at the rim, 3–3.5 cm; inside depth, 4 cm; and wall thickness, 0.25–1.0 cm.

Nest building observed at 25 nests in Pope County required 3–5 days with very little time (not more than a day) between the comupletion of the nest and the laying of the first egg. The gnatcatcher is par-

TABLE 3.—Nest sites of the blue-gray gnatcatcher in different regions of Illinois.

Tree Species	Number of Nests		
	North	Central	South
Elms, *Ulmus* sp.		1	2
Winged elm, *U. alata*			12
Slippery elm, *U. rubra*			1
American elm, *U. americana*			1
Oaks, *Quercus* sp.			2
White oak, *Q. alba*		1	10
Red oak, *Q. rubra*		1	1
Spanish oak, *Q. falcata*			1
Cherrybark oak, *Q. falcata pagodaefolia*			1
Chinquapin oak, *Q. muhlenbergii*			1
Shingle oak, *Q. imbricaria*			1
"Swamp oak"			1
Sugar maple, *Acer saccharum*			5
Scyamore, *Platanus occidentalis*		2	3
Black walnut, *Juglans nigra*		5	
River birch, *Betula nigra*			4
Sassafras, *Sassafras albidum*			3
Honey locust, *Gleditsia triacanthos*			3
Ash, *Fraxinus* sp.			2
Willow, *Salix* sp.	1	1	
"Shellbark hickory"		1	
Persimmon, *Diospyros virginiana*			1
Ironwood, *Ostrya virginiana*			1
Wild black cherry, *Prunus serotina*			1
Sour gum, *Nyssa sylvatica*			1
Hackberry, *Celtis occidentalis*			1
Loblolly pine, *Pinus taeda*			1

asitized by the cowbird (Fig. 6), sometimes heavily (Friedmann 1963), and often abandons its nest, seemingly as a result of cowbird activity. Little time elapsed between the abandonment of a nest and the building of another. In most cases we saw the pairs removing nest material from the earlier nest, using it to rebuild before we were aware that they had given up the former attempt. At least four pairs each built three different nests in one season (1973). A large part of the gnatcatchers' energy budget is spent on nest building.

It may be that the most efficient way to build quickly in another site is to reuse the material from the abandoned nest. Bent (1949) has suggested that the gnatcatcher reuses its nesting materials because of the brief seasonal occurrence of the materials, e.g., oak catkins. A scarcity of desirable nesting material is suggested by the observation of Comfort (1954), who saw a yellow-throated warbler *(Dendroica dominica)* pilfering nest material from a gnatcatcher's nest in the St. Louis area. Subsequent nests are often fairly close to the previous nest site. Mrs. William Carroll of Woodstock observed a pair rebuilding only 15 m from the earlier nest.

The eggs of the gnatcatcher are pale bluish white, with irregular spots of reddish brown (Fig. 6). The egg-laying season extends from at least 18 April to 18 June in southern Illinois (Fig. 3). We have data on clutch size from only 12 nests for Illinois: 2 eggs, one set; 3 eggs, one; 4 eggs, seven; and 5 eggs, three sets. It is not known whether the gnatcatcher is double brooded in Illinois.

Both adults incubate the eggs. In 90 minutes' observation, J. Graber saw the female of one pair

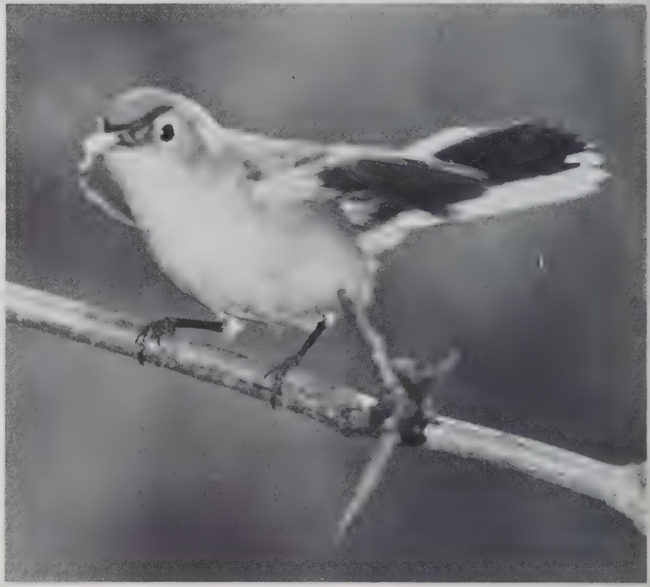

Fig. 5.—Blue-gray gnatcatcher carrying building material for its nest, 5 May 1973 in Pope County. Note the bird's white outer tail feathers.

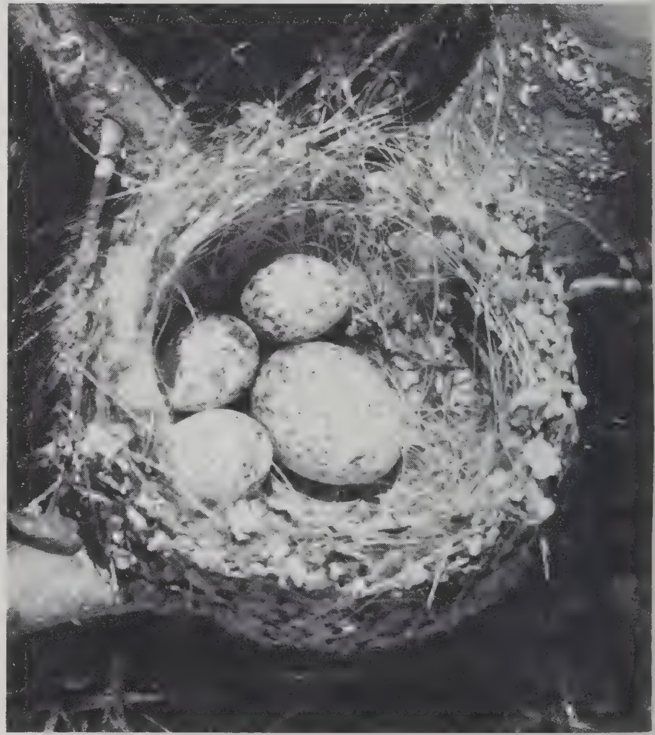

Fig. 6.—Nest with eggs of the blue-gray gnatcatcher and one cowbird egg. Photographed 11 May 1973 in Pope County.

spend 10 minutes setting, leave, return shortly, and spend 8 more minutes on the nest before she was relieved by the male. He spent 10 minutes on the nest before the female returned and sat for 20 minutes. The male then sat for 30 minutes before the female came back. She was on the nest when observation ceased. A female gnatcatcher was observed feigning injury for a distance of 90 m when flushed from eggs that she had been incubating for 4–5 days.

The incubation period is around 13 days, and the young spend at least 11 days in the nest with both parents caring for them. How long after fledging the young are cared for by the adults is unknown, but young nearly as large as the adults have been observed being fed by the adults. The total length of the nest cycle from the beginning of the nest to fledging is 33–38 days. Renesting attempts ceased in early July in 1973 in southern Illinois.

Gnatcatcher territory size is small. For 25 pairs of gnatcatchers observed in 1973 in an area of about 36 ha of habitat (upland wooded ravines and a small stream) the territory size appeared to be about 0.37 ha.

Our observations of a gnatcatcher population in upland habitat in Pope County in 1973 showed nesting success to be very poor. Of 31 nests built by 20 pairs, only 4 fledged gnatcatchers, and 1 nest fledged a cowbird but no gnatcatchers. More data are needed on the productivity of gnatcatchers in both upland and bottomland habitats. Because of their size and locations, it is difficult to see the contents of most gnatcatcher nests, and thus, difficult to obtain precise histories. Causes of nest failures included at least the following—cowbird activity, predation, and weather. Wind was noted as the cause of destruction of gnatcatcher nests in northern and central Illinois (Loucks unpublished 1890; Mrs. W. Carroll unpublished 1964; M. F. Campbell unpublished 1974).

In mid- and late summer, gnatcatchers become very quiet and inconspicuous. Some are still caring for fledged young in late July. Sanborn (1921) saw adults with full-sized young at Beach on 24 July, and Nelson (1877) reported "half-fledged" young at Mt. Carmel at the last of July.

The post-nuptial molt may be early, as we saw a male which appeared to be in fresh plumage on 28 July 1973 in Pope County.

Fall Migration

The onset of the fall migration of gnatcatchers is difficult to determine. As in most species with small populations to the north of Illinois, the fall migration of the blue-gray gnatcatcher is relatively inconspicuous here (Fig. 3). The last dates when gnatcatchers have been reported by observers in various northern Illinois localities range from 22 July at Port Byron (Schafer 1917–1918) to 7 October at Rockford (Van Duzer 1920). In central Illinois last dates on which gnatcatchers have been seen range from 27 July at Allerton Park (Bursewicz 1961) to 15 October at Rantoul (Bent 1949) and 16 October at Monmouth (Kleen 1978). Records of departure from the southern Illinois region range from 10 September (George 1968) to 12 October (Jones 1935). The highest fall counts of gnatcatchers have occurred between 1 and 6 September in southern and central Illinois (Fig. 3). The ratio of our spring-to-fall counts was about 11 gnatcatchers in spring (April–May) to 1 in fall (August–September), perhaps reflecting the inconspicuousness of the species in the fall.

The migration of gnatcatchers has apparently never been seen directly, and its characteristics are unknown, fall or spring. No specimens of gnatcatchers have been recovered from television tower kills in Illinois, but species with low populations north of Illinois are rarely killed on Illinois towers, and none are to be expected.

Food

There are no published accounts on the food of the blue-gray gnatcatcher in Illinois, and data are much needed.

Specimen Data

Ridgway (1904) said that the nominate race *(P. c. caerulea)* was the breeding form in Illinois and gave these average measurements from a series that included Illinois specimens: wing, 52.8 mm (male) and 50.5 (female); tail, 50.7 mm (male and female); tarsus, 17.1 mm (male) and 17.2 (female); exposed culmen, 9.8 (male) and 10.0 (female).

GOLDEN-CROWNED KINGLET
(Regulus satrapa)

(Fig. 7 and 8)

Spring Migration

Because golden-crowned kinglets winter in Illinois, the exact beginning of the spring migration may be obscured by the presence of the winter population. This is particularly true in southern Illinois, where the difference between winter population densities and spring densities appears to be subtle (Fig. 9). The migration of kinglets has never been seen directly, but is presumed to be nocturnal (see Fall Migration).

In central Illinois, Musselman (1931) noted a definite increase in golden-crowns on 16 February, but most observers do not detect influxes until the latter half of March (Anonymous 1916, 1917; Craigmile 1918; Gault 1901*a*). In central and northern Illinois, spring counts of golden-crowns show a definite peak between 20 March and 12 April (Fig. 9).

Fig. 7.—Golden-crowned kinglet. The crown is yellow in the female, bright orange and yellow in the male.

Especially notable influxes of golden-crowns have been reported at the end of March (Fawks 1967; Musselman 1934–1935), but counts of as many as 100 golden-crowns per day are exceptional. Most of the population has passed through Illinois by the end of April. We have never detected golden-crowned kinglets in Illinois in May, but there are some reliable records for that month, as late as the 6th in southern Illinois (Cooke 1915), the 18th in central Illinois (Fawks 1972), and the 27th in northern Illinois (Clark & Nice 1950; Kleen 1975*b*). A reference to golden-crowns having remained all summer near Polo (Cooke 1888) is of uncertain validity.

Our spring counts of golden-crowns were extremely variable (Fig. 9), but such variation may not be unusual for the species (Nolan 1955). Because of their small size, kinglets are subject to winterkill, a phenomenon that would cause spring counts to be low in some years (Nolan 1956*a*, and see Winter Populations). The apparent regional variation in our counts, we suspect, is actually annual variation from causes unknown. During the migration seasons golden-crowned kinglets probably occur in every township in the state.

Kinglets are primarily arboreal species, and though they also forage on herbaceous plants, they are not likely to be found far from woody hatitat—at least shrubs. They are often found in association with conifers (Swink 1965).

We have rarely heard golden-crowned kinglets sing in Illinois. Peattie (1938) characterized the song as lovely—rising in a sweet twitter—and he, as well as Farwell (1919) and Gault (unpublished) heard the song in northeastern Illinois. In contrast to the song, the call—a very high-pitched, often three-noted "tree-tree-tree"—is uttered frequently at all seasons (Baldwin 1941).

Fall Migration

Though golden-crowned kinglets nest at least as close as northern Wisconsin (Fig. 8), they do not begin to reappear in Illinois until September. The earliest fall records are 12–14 September in northern Illinois (Roberts 1921; Ford 1932; Blake & Smith 1941; Clark & Nice 1950), 21 September in central

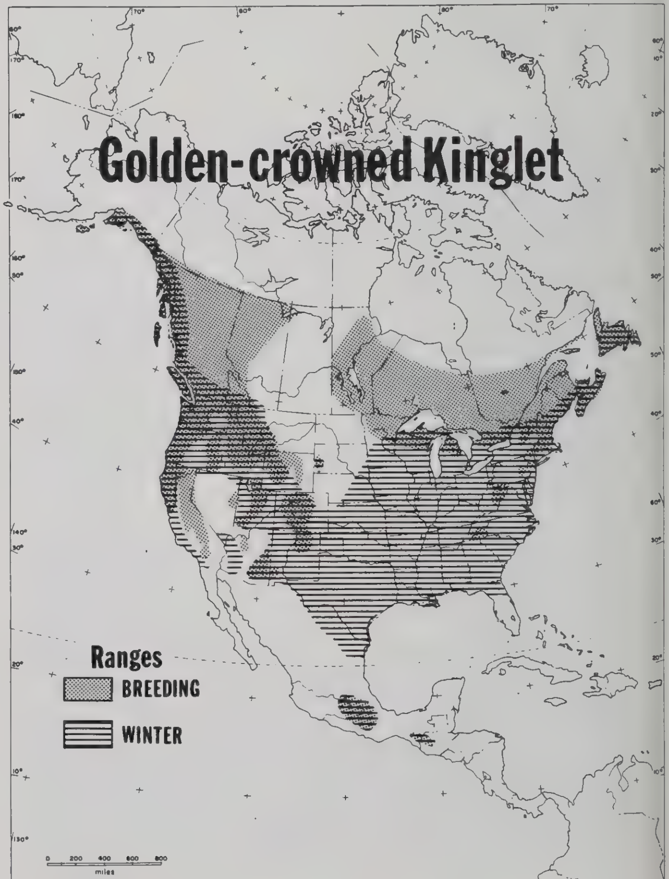

Fig. 8.—General distribution of the golden-crowned kinglet.

Illinois, and 26 September in southern Illinois (Jones 1940). The population of transient golden-crowns remains relatively high through October in central and northern Illinois and then usually drops off in November (Fig. 9), but Patterson (1920) and Musselman (1930) reported golden-crowns to be numerous in late November and early December, suggesting late migration waves. In northeastern Illinois during 8

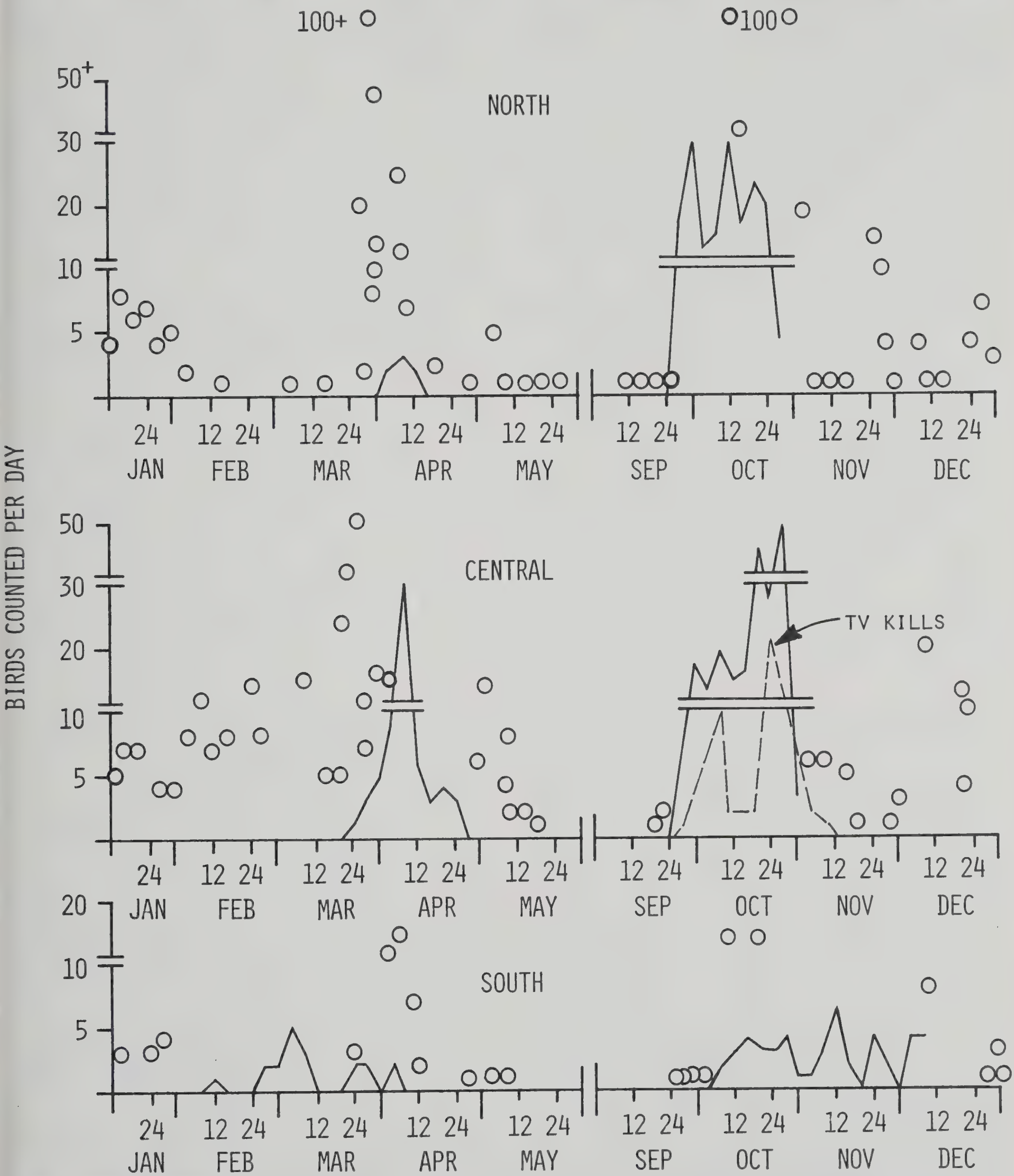

Fig 9.—Migration seasons of the golden-crowned kinglet in different regions of Illinois. Spring and fall graph lines show the highest daily count of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers.

years of observation, Gault (1901*b*) noted the latest golden-crown on 11 December. In the St. Louis area Widmann (1907) stated that the bulk of the transient golden-crowns passed on 10–20 October and that the last moved through during the first week of November. The end of the fall migration, like the beginning of the spring migration, is obscured by the presence of wintering birds. Our southern Illinois counts show little evidence of "peak" flights of transients (Fig. 9), but the same census route that yielded three to six golden-crowns in October and November produced only one or, more often, none at all in late December; so we would judge that most of the transients have passed the southern region by mid-December. Anderson's (1964) statement that golden-crowns were common at St. Louis in early December but uncommon later points to the same conclusion.

The migration waves of kinglets in fall are clearly associated with the passage of cold fronts (Bennett 1952; Wasson & Shawvan 1953; Nolan 1956*b* and 1958). Overnight changes in the kinglet population (Bennett 1952; Wasson & Shawvan 1953) indicate the migration to be nocturnal, and golden-crowns are sometimes killed with other night migrants on television towers (Petersen 1959; Seets & Bohlen 1977). Golden-crowns have been killed at central Illinois towers between 27 September and 12 November, in which period they constituted 0.8 percent (39 birds) of about 4,700 birds of all species picked up between 1955 and 1972. They constituted a much higher percentage (3.6) of the October kills (about 1,000 birds of all species). It can be seen in Fig. 9 that the numbers of golden-crowns killed on central Illinois towers show a similar pattern to the numbers seen in the field.

The ratio of our spring (February–May) to fall (September–November) counts was very low—1 in spring to 7 in fall—for the state as a whole, but varied greatly from region to region—1 to 25 in the north, 1 to 5 in central Illinois, and 1 to 3 in the south. The extraordinary ratio in the north can be attributed in part to the very poor spring count in the year (1968) when the north was censused. William Dreuth recorded golden-crowns about twice as often in fall as in spring (Clark & Nice 1950; Eiseman & Shank 1962), but this was only a measure of frequency and not of numbers of birds seen. To interpret the spring:fall ratios, we need data on age ratios (i.e., productivity) and migration routes of golden-crowns. In our very small sample (6) of aged fall specimens of golden-crowns, the ratio of adults to immatures was 1.0 to 2.5, or the equivalent of a spring:fall ratio of 1.0 to 3.5, which is at least roughly comparable to the ratios we recorded in central and southern Illinois.

Winter Populations

As with most species, the specific factors that affect the population size and distribution of kinglets are unknown. Golden-crowns probably occur in every Illinois county during the winter, though records are still lacking for many (Fig. 10), reflecting lack of coverage. The number of golden-crowns recorded on Christmas counts fluctuates greatly from year to year, with no consistent pattern (Fig. 11). Surprisingly, the counts also show no consistent difference from region to region and no significant correlation between regions. More precise censuses (Table 4) suggest that southern Illinois populations are higher than those to the north, and the Christmas counts may lack enough precision to show regional differences.

Swink (1965) observed that golden-crowns are most often associated with evergreens, and that also is our impression of the habitat preference, but there are no population figures for golden-crowns in any coniferous habitat in Illinois. No measurable populations

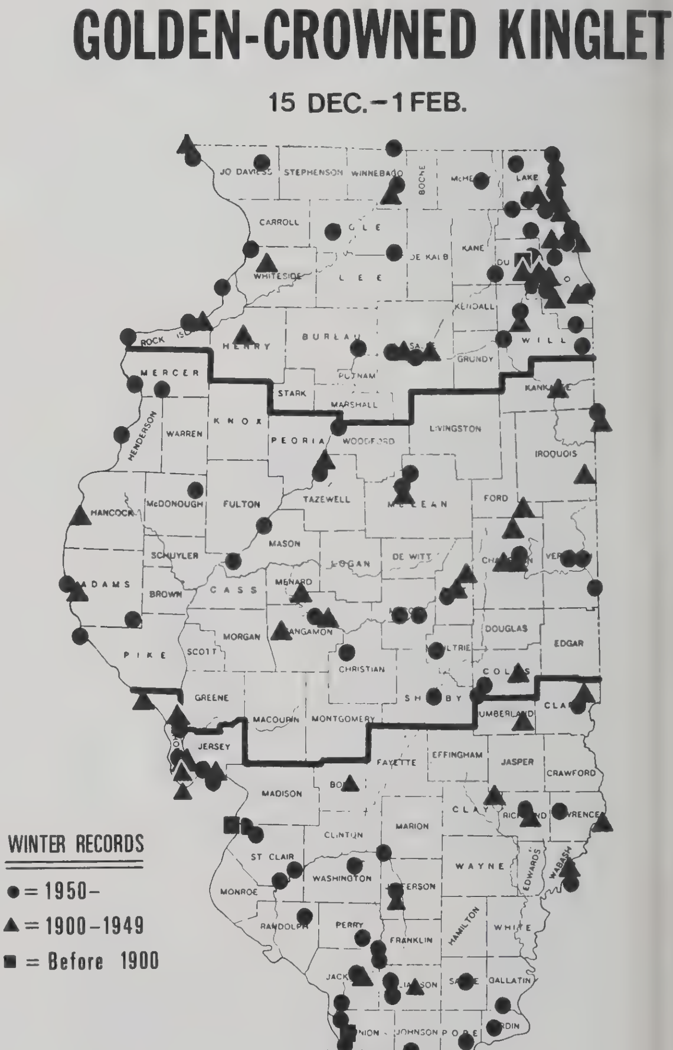

Fig. 10.—Winter records of the golden-crowned kinglet in Illinois. Heavy horizontal lines separate the three regions (north, central, and south) referred to in the text.

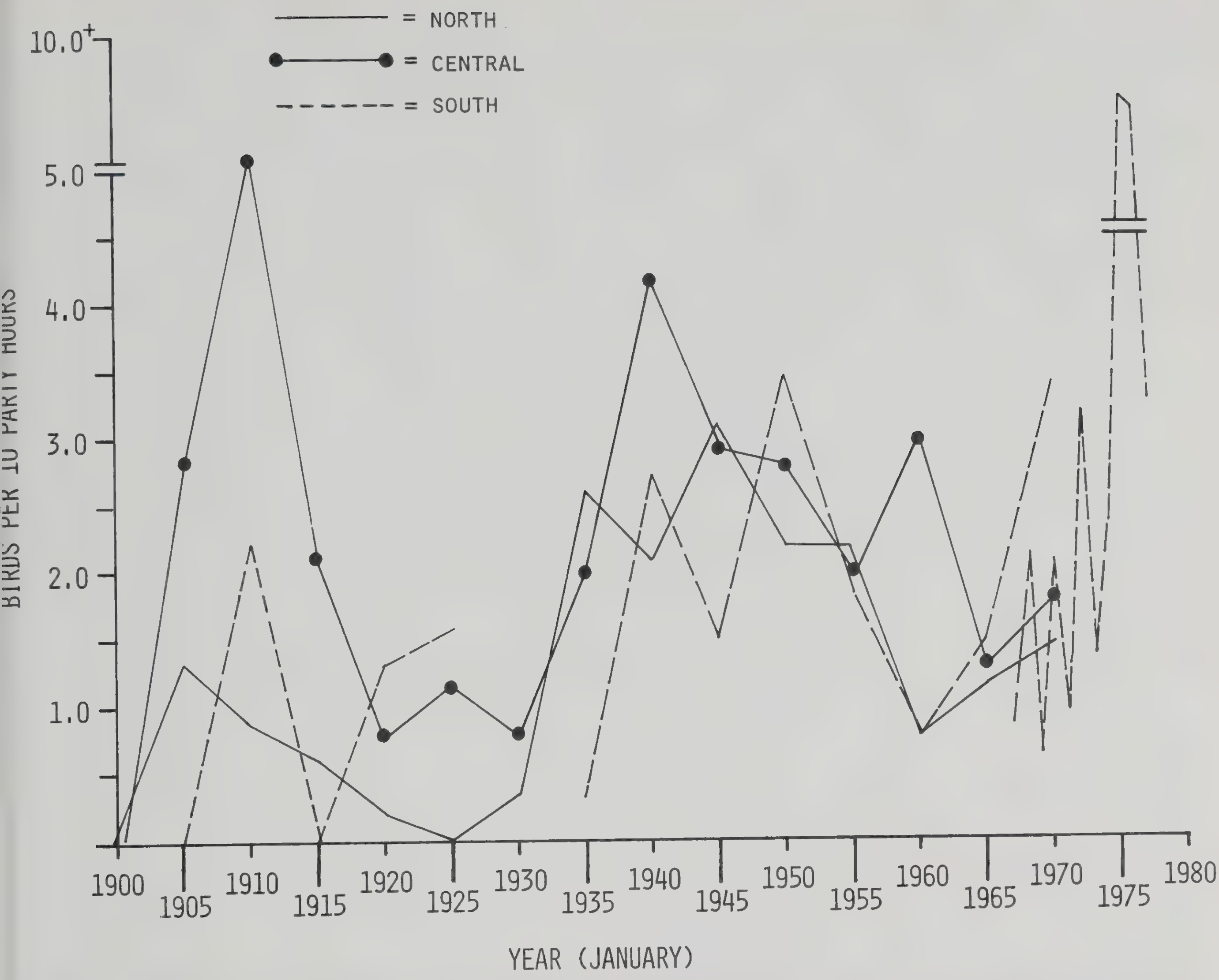

Fig. 11.—Golden-crowned kinglets seen per 10 party hours on Audubon Christmas counts in the three regions of Illinois. Each point represents a 5-year average. Annual variation in the counts for the last 10 years is shown for the southern region.

have been reported in other than woody habitats, and based on population densities, forest (of deciduous habitats) is preferred (Table 4). Shrub areas and urban habitat both have much lower populations of golden-crowns. Our censuses of southern Illinois forests (Graber et al. 1977) show a high degree of correlation ($r = 0.944$, $P = 0.01$) between golden-crown populations in bottomland and those in upland forests in various years, but our counts show no correlation with the Christmas counts in the same years (Fig. 12).

There was no significant difference in densities of golden-crowns between bottomland and upland forest habitat, and we could find no character (basal area, stem densities, Importance (Y) of any genus of tree or shrub) that correlated with golden-crown populations.

For their size, kinglets are remarkably cold hardy, but the extremely cold winter of 1976–1977 caused catastrophic population losses among golden-crowned and ruby-crowned kinglets (Graber & Graber 1979). Golden-crowns were present in normal numbers in our southern Illinois forest study areas in early January 1977, but by mid-February they had disappeared, and the population showed little recovery by the following year (Fig. 12 and Table 4). A similar kill probably occurred in January 1956 (Nolan 1956*a*), which accounts for the near absence of kinglets in Illinois in 1957 and 1958 (Tables 4 and 5).

Food

Both golden-crowned and ruby-crowned kinglets forage from the tops of the trees to near the ground, but we have never seen a live one on the ground. They move quickly and almost continuously, looking over branches, leaves, buds, and flowers of woody as well as herbaceous plants. They often flutter at the tip of a branch, picking up food as they hover. They appear to take their food from the surface of the

TABLE 4.—Winter populations of golden-crowned kinglets in various Illinois habitats.

Habitat	Hectares	Birds per 40.5 ha	Years (January)	Type of Census	Region or County	Reference
Urban residential	173	0	1976, 1978	Strip	North & Central	This paper
Urban residential	273	0	1976–1978	Strip	South	This paper
Suburban woodlot	8	0–5 (avg 1)	1968–1972	Map	Lake (N) [a]	Miller & Miller 1972
Forest (all types, including edge)	18	0	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	62	0–1 (avg 0.6)	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	85	0	1957–1958	Strip	South	Graber & Graber 1963
Oak-maple forest and edge	23	0–4 (avg 0.5)	1925–1943	Map	Champaign (C)	Kendeigh 1944
Oak-maple forest and edge	23	0–4 (avg 1.1)	1944–1948	Map	Champaign (C)	Kendeigh 1948*a*
Oak-maple forest and edge	23	0–2	1949–1976	Map	Champaign (C)	Kendeigh et al. 1953
Bottomland elm-maple forest	20	0–4 (avg 2.0)	1950–1953	Map	Cook (N)	Montague 1950, 1953
Grazed bottomland forest	21	2	1955, 1957	Map	Macon (C)	Chaniot & Kirby 1955*a*, Kirby & Chaniot 1957
Mature bottomland forest (1 year after blizzard)	60	0	1978	Strip	Piatt (C)	This paper
Mature bottomland forest (before blizzard)	644	0–10 (avg 5.5)	1974–1977	Strip	South	This paper
Mature bottomland forest (after blizzard)	186	0	1977	Strip	South	This paper
Mature bottomland forest (1 year after blizzard)	306	0–4 (avg 0.9)	1978	Strip	South	This paper
Mature upland forest (1 year after blizzard)	81	0	1978	Strip	Piatt (C)	This paper
Mature upland forest (before blizzard)	341	0–7 (avg 5.6)	1974–1977	Strip	South	This paper
Mature upland forest (after blizzard)	91	0	1977	Strip	South	This paper
Mature upland forest (1 year after blizzard)	176	0–2 (avg 0.2)	1978	Strip	South	This paper
Shrubby field and forest edge	34	0– (+) [b]	1955–1956	Map	Richland (S)	Shaw & Stine 1955, Shaw et al. 1956
Shrubby field	16	0– (+)	1958–1965	Map	Lawrence (S)	Shaw 1958, 1962
Shrubby field	16	2	1968	Map	Lawrence (S)	Hundley et al. 1968

[a] N refers to the northern region of Illinois, C to the central region, and S to the southern, as shown on winter distribution maps, e.g., Fig. 10.

[b] The plus symbol (+) indicates fewer than one bird per 40.5 ha.

plant, but the food is so small, and the birds so quick that we have never seen what it is that they eat. Forbes (1882) examined the stomachs of 18 golden-crowns (4 from spring, 12 from fall, and 2 from winter) and 30 ruby-crowned kinglets (26 spring, 2 fall, and 2 winter); so his spring data represent primarily ruby-crowns and the fall data, primarily golden-crowns. Forbes (1882) considered the habits of the two species of kinglets to be so similar that, in his discussion of their food, he lumped the data for the two. In spring, dipterans (gnats) were the most common food (33 percent of the total), with beetles (25 percent)—especially leaf-eating beetles *(Xanthonia decemnotata)* and scavenger beetles *(Aphodius inquinatus, A. femoralis)*—nearly as important. In fall, Lepidoptera (33+ percent)—especially winged moths—and Hemiptera and Homoptera combined (29 percent) were the most important food groups for kinglets. In winter, hemipterans (39 percent), mistletoe fruit (25 percent), spiders (17 percent), and cutworms (16 percent) were the dominant foods. The kinglets are apparently opportunistic, taking insects that are in ample supply and sometimes feeding exclusively on one species.

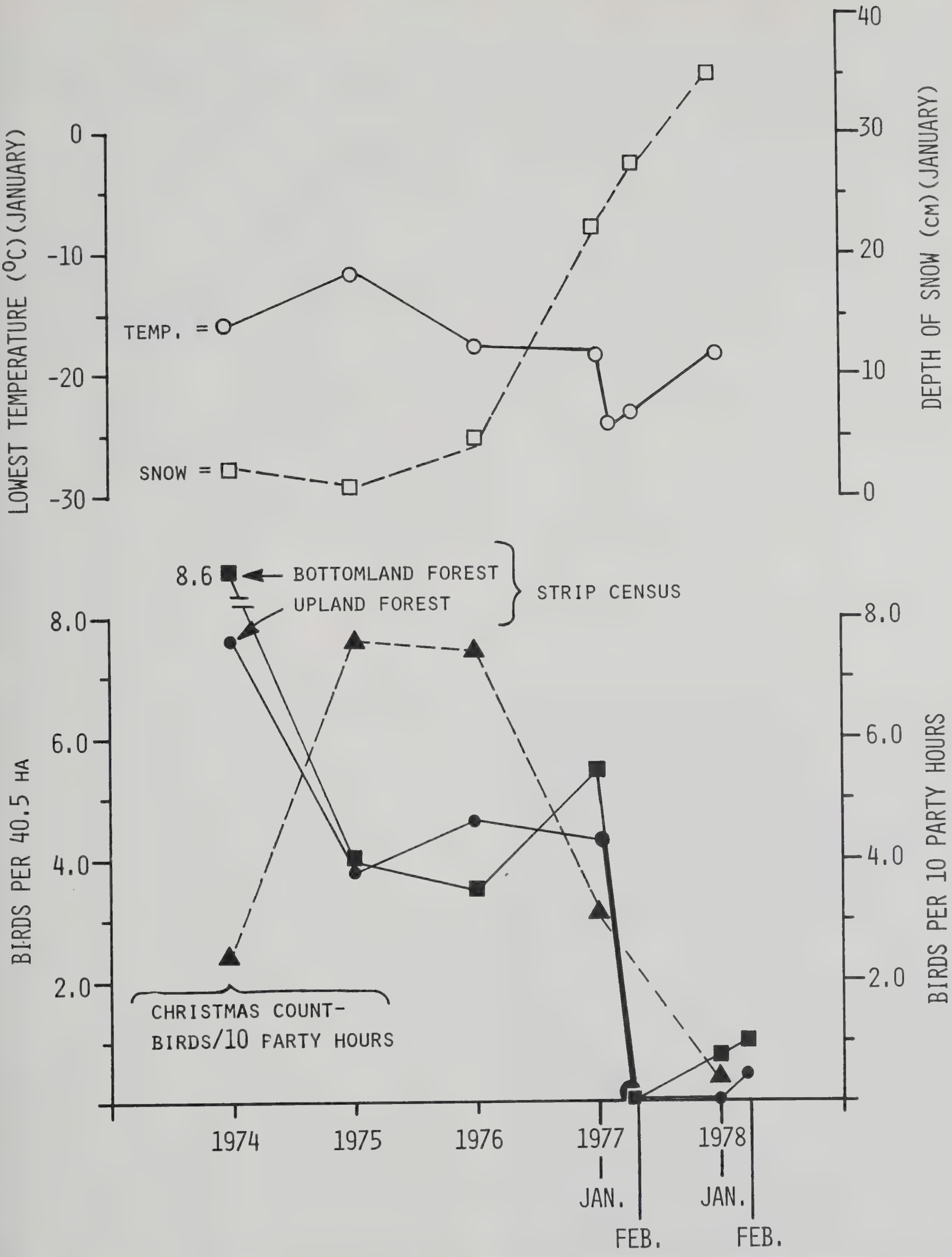

Fig. 12.—Comparison of Christmas counts with winter strip censuses of golden-crowned kinglets in bottomland and upland forests of southern Illinois, 1974–1978, inclusive. February data are shown for 1977 and 1978 only. The upper panel shows accompanying extremes of temperature and snow cover in the region. Note that the population crashed between January and February of 1977, coinciding with extreme cold, though the Christmas count did not show this decline until 1978.

Needham (1909) referred to "scores" of kinglets having been caught on the bristly heads of burdock plants near Lake Forest in October. He believed that the birds had been attracted to an abundant food supply, and mentioned particularly the larvae of a small moth *(Metzneria lapella)* and of the "burdock weevil."

Specimen Data

We have examined only 15 specimens (8 males, 7 females), all of which represent the eastern form *(R. s. satrapa).* Three October males (moderately to very fat) ranged in weight from 5.7 to 7.4 g (mean: 6.6 g). An October female (very fat) weighed 6.1 g.

RUBY-CROWNED KINGLET

(Regulus calendula)

(Fig. 13 and 14)

Spring Migration

The beginning of the spring migration of ruby-crowned kinglets in Illinois is not usually detected before late March or early April, with little or no difference in arrival dates between southern and northern Illinois (Fig. 15). An exceptional number of ruby-crowns (100) was seen on 30 March 1967 on the Chicago lakefront (Fawks 1967), but we do not usually see more than 20–30 per day in spring, with peak numbers passing from about 12 April to 1 May.

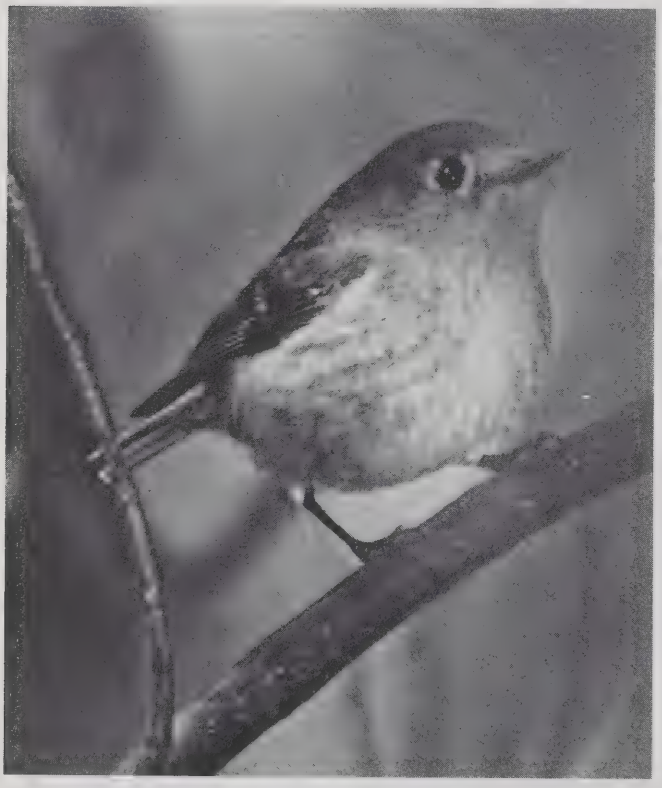

Fig. 13.—Ruby-crowned kinglet photographed in Piatt County, May 1971. Females lack the red crown patch for which the species is named.

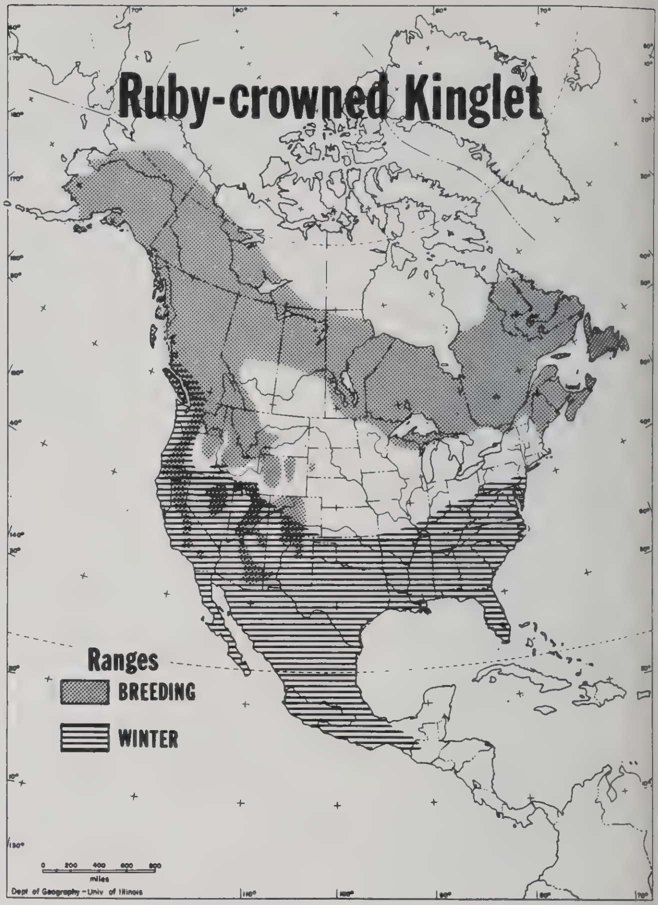

Fig. 14.—General distribution of the ruby-crowned kinglet.

Most of the ruby-crown population has passed through southern Illinois by the end of April, but there are records as late as 14 and 15 May (Cooke 1915, George 1968). In central and northern Illinois the transient population of ruby-crowns may remain relatively high in some years even until mid-May. Generally, few are seen after that time, but stragglers have been seen in central Illinois as late as 4 June (H. D. Bohlen unpublished) and in northern Illinois on 8 June (Ford 1956). So far as is known, the migration is nocturnal (see under Fall Migration).

Ruby-crowns are an arboreal species, foraging from near ground level to the tree tops. It is our impression that ruby-crowns usually forage lower in the vegetation than do golden-crowns, but specific quantitative data on foraging heights and preferred plants are lacking for both species of kinglets in all habitats and all seasons. Both Silloway (unpublished 1921–1924 typescript, Peoria Public Library) and Swink (1965) mentioned that ruby-crowns were feeding in hawthorns and other small trees in spring.

As do some other transient species, some ruby-crowned kinglets appear to set up "territories" during their passage through Illinois, especially in April. Males defend their areas against other males in a

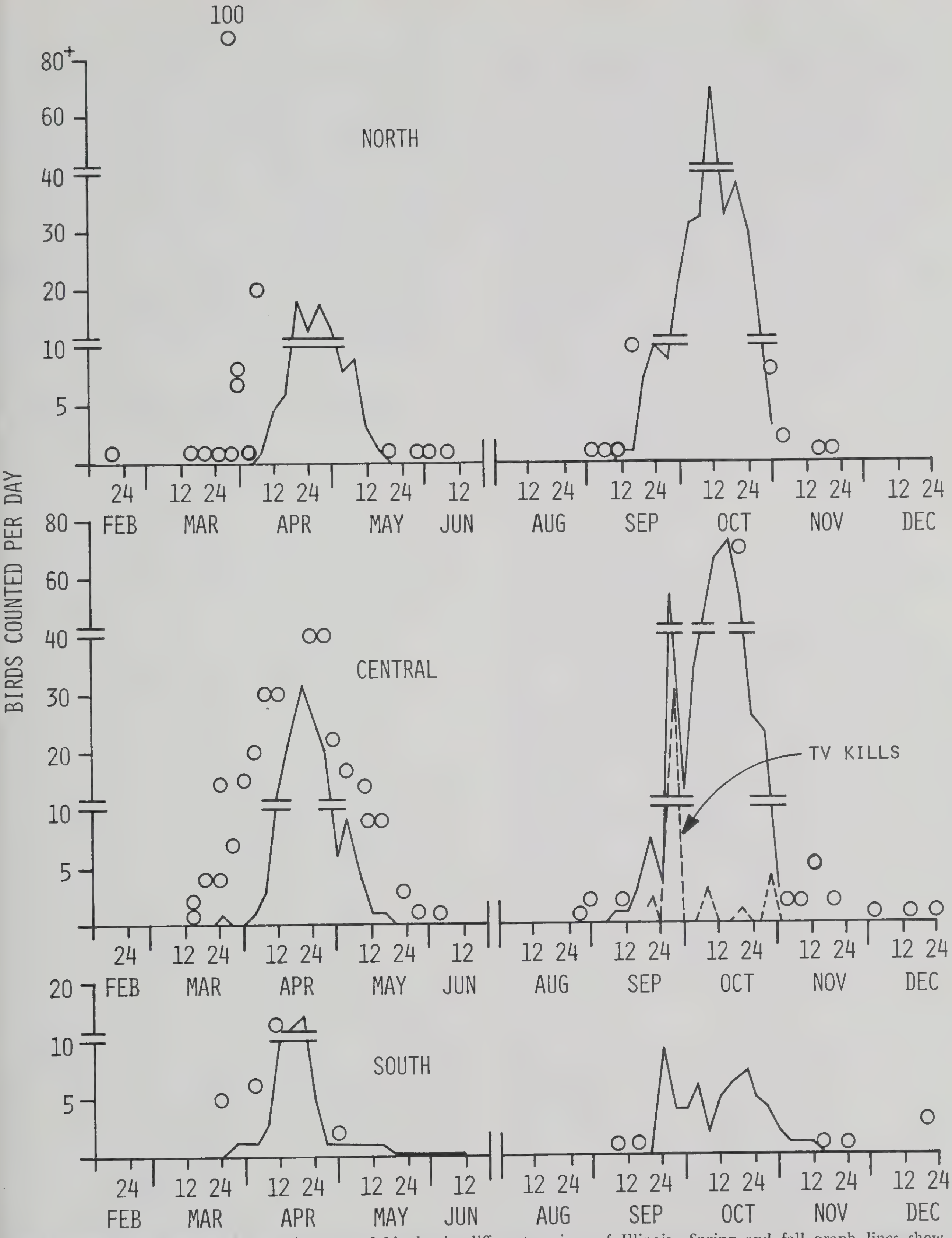

Fig. 15.—Migration seasons of the ruby-crowned kinglet in different regions of Illinois. Spring and fall graph lines show the highest daily counts of each 4 days (1967–1970). Hollow circles represent counts made in other years or by other observers. Dash line shows the number of ruby-crowned kinglets killed at television towers in central Illinois, 1955–1972.

ritualistic display. As two males face one another the red crown feathers are raised rapidly, making the whole top of the head appear red. The birds arch their necks, pointing the ruby crowns toward one another, and then fly in circles about one another, all the while singing frequently. The length of time that these "territories" are held cannot be known without studies of banded birds, but some individuals appear to stay in the same area for as long as a week.

In contrast to the golden-crown, male ruby-crowned kinglets are strong and persistent singers in both spring and fall. Ridgway (1889) described the song as a delicate, musical warble, astonishingly protracted and beautifully varied by rising and falling cadences. The song sometimes seems amazingly loud considering the size of the singer. Even more frequently, ruby-crowns utter a short explosive, double-noted call ("cha-ret") and sometimes a harsh chattering, suggestive of the scold notes of the house sparrow (Farwell 1919).

Fall Migration

Ruby-crowned kinglets nest as close as northern Wisconsin (Fig. 14), and the earliest the southward migration has been detected is 24 August in the north (Kleen 1978) and 28 August in central Illinois (A. O. Gross 1904 unpublished). However, the species is not usually seen in Illinois again until early or mid-September, marked influxes often being noted about 20 September with little variation in timing between different regions of the state (Fig. 15). Our counts indicate peak populations between 24 September and 24 October, falling off sharply by the end of October. P. C. Petersen banded 273 ruby-crowns on 16 October 1966 near Rock Island, indicating a very large concentration. We suspect that there are occasional migration waves of ruby-crowns in November and even December, but the available counts for those months are all low (Fig. 15). The actual end of the fall migration is possibly obscured by a thin and highly variable winter population.

Ruby-crowned kinglets have been killed at central Illinois television towers with other nocturnal migrants between 20 September and 12 November, in which period they constituted nearly 1.0 percent (46 specimens) of about 4,700 specimens of all species picked up from 1955 through 1972. Ruby-crowns accounted for only 0.8 percent of the October kills, and in contrast to the golden-crown, there was no correlation between counts of kinglets killed at the towers and counts of kinglets seen in the field. Few ruby-crowns are killed on the towers in relation to the numbers seen (Graber 1968), but the reason for this may have more to do with weather than with what the birds are doing. Kills at central Illinois towers seem to be *generally* reduced in mid-October, the time of peak ruby-crown populations.

The ratio of our spring (March–May) to fall (September–November) counts of ruby-crowned kinglets was 1.0 to 2.8 for the state as a whole, but the ratio declined progressively from northern Illinois (1:3.4), to central (1:2.9), to southern Illinois (1:1.7). This is a pattern we have observed in a number of species, including the golden-crowned kinglet, and is probably indicative of an elliptical migration route which brings different populations through the state in the spring and fall (Graber 1968). The only published band recovery we've found (Bent 1949) which indicates flight direction was that of a ruby-crown banded 18 April 1937 at Waukegan and recovered 10

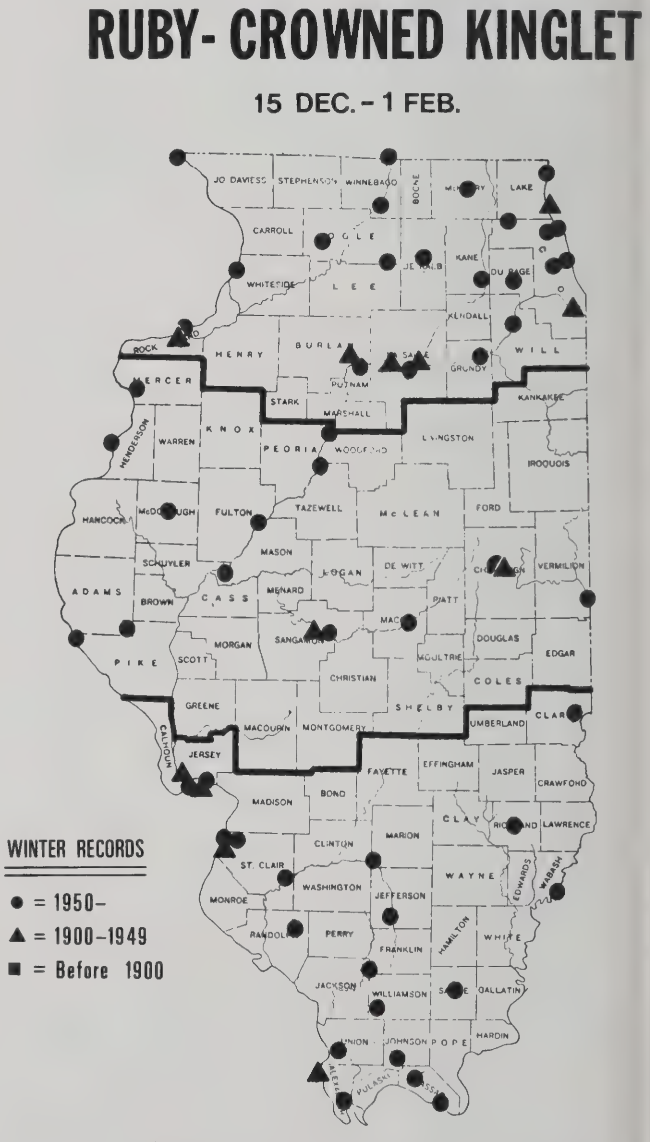

Fig. 16.—Winter records of the ruby-crowned kinglet in Illinois. Heavy horizontal lines separate the three regions of the state.

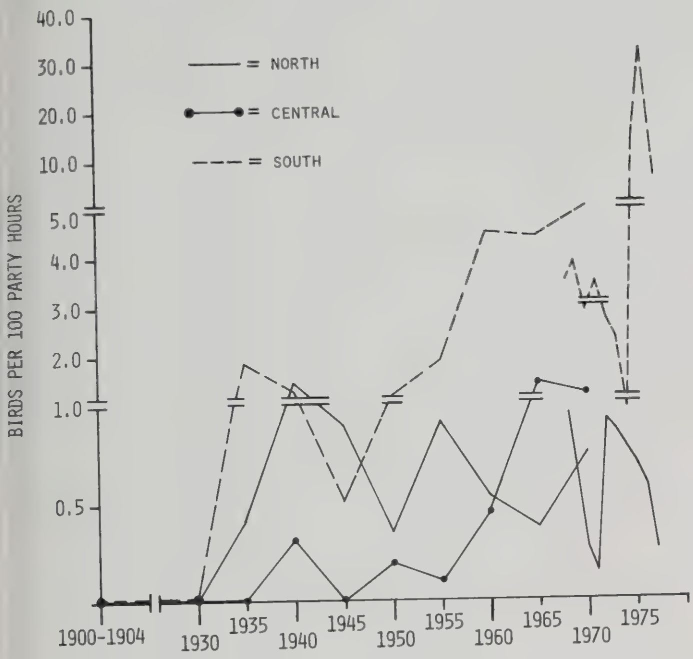

Fig. 17.—Ruby-crowned kinglets seen per 100 party hours on Audubon Christmas counts in the three regions of the state. Each point represents a 5-year average (e.g., the point for 1935 represents the counts for 1935–1939). Annual variation in the counts for the last 10 years is shown for the northern and southern regions.

days later at Green Lake, Wisconsin (about 70 km NNW).

Winter Populations

Prior to about 1930 there were very few records of ruby-crowned kinglets in Illinois in midwinter (Roberts 1922, Ford et al. 1934, Carpenter 1935). Note that most of the records shown in Fig. 16 are relatively recent. Ridgway (1874) noted that the species sometimes wintered in southern Illinois, but later (Ridgway 1889) made no mention of the species in winter. In B. T. Gault's extensive notes (1875–1927) on northeastern Illinois, we have found no winter record of the species. After 1930 ruby-crowns were detected with increasing frequency on the Christmas counts in southern and central Illinois but not in the north (Fig. 17). On the average, since 1940 it has taken about 178 party hours to find a ruby-crowned kinglet on the Christmas counts in northern Illinois, 139 hours in central Illinois, and 39 hours in the south, with the time requirement declining to only 10 hours in southern Illinois in the 1970's. In interpreting such data there is always the question of whether the population increase is real or only apparent because of the increased numbers and competency of participants in the counts.

There is other evidence of an increase in wintering ruby-crowns in Illinois during this century. Alfred Gross and Howard Ray did not detect ruby-crowns in winter on the cross-country censuses of 1907, whereas we encountered the species in both 1957 and 1958—though only in shrub habitat (Graber & Graber 1963). Judging from population densities, we believe that ruby-crowns greatly prefer bottomland forest to upland forest as winter habitat (Table 5). This preference is in contrast to that of the golden-crowned kinglet, which was as prevalent in upland as bottomland tracts. No characteristic that we measured in 15 different forests was correlated with kinglet populations (see under golden-crowned kinglet—Winter Populations). Shrub areas, with densities of 2 ruby-crowns per 40.5 ha in 1957–1958, would seem to be an important winter habitat, but the highest population we've measured was 7 birds per 40.5 ha in mature bottomland forest (Union County Refuge).

The blizzard of January 1977 had a devastating effect on the populations of kinglets, virtually eliminating both species in Illinois. Ruby-crowns showed relatively stronger recovery than golden-crowns by the following year (Table 5). In general, ruby-crowns winter much farther south than do golden-crowns (Fig. 8 and 14), and we would expect more ruby-crowns to survive and reproduce.

Our census data show a pattern of alternate-year highs in the ruby-crown population, with average densities in mature bottomland forest of 0.2 bird per 40.5 ha in (January) 1974, 2.1 in 1975, 0.2 in 1976, 1.3 in 1977 (before the blizzard), and 1.0 in 1978. The highs occur in the odd-numbered years, as in the case of the red-headed woodpecker *(Melanerpes erythrocephalus),* a species (of very different food habits) which also favors bottomland forest in the south. The run of years for which we have data is still too short to be conclusive, especially in view of the relatively high ruby-crown population in 1978. Christmas count data do not show the alternate-year pattern (Fig. 17), but in general we find the Christmas data to be insufficiently refined to show such patterns. The Christmas counts show no correlation with our census data.

Food

See golden-crowned kinglet account.

Specimen Data

We have examined only 12 specimens (3 spring males, 2 fall males, 4 spring females, 3 fall females). They fall within the range of color and size variation of *Regulus c. calendula.* A winter specimen from northern Illinois was also considered to be of the nominate race (American Ornithologists' Union 1957). We have weight data on five specimens: September

Table 5.—Winter populations of ruby-crowned kinglets in various Illinois habitats.

Habitat	Hectares	Birds per 40.5 ha	Years (January)	Type of Census	Region or County	Reference
Urban residential	173	0	1976, 1978	Strip	North & Central	This paper
Urban residential (before blizzard)	106	0–1 (avg 0.4)	1976–1977	Strip	South	This paper
Urban residential (after blizzard)	167	0	1977–1978	Strip	South	This paper
Forest (all types, including edge)	18	0	1957–1958	Strip	North	Graber & Graber 1963
Forest (all types, including edge)	62	0	1957–1958	Strip	Central	Graber & Graber 1963
Forest (all types, including edge)	85	0	1957–1958	Strip	South	Graber & Graber 1963
Mature bottomland forest (1 year after blizzard)	60	0	1978	Strip	Piatt (C)[a]	This paper
Mature bottomland forest (before blizzard)	644	0–7 (avg 0.9)	1974–1977	Strip	South	This paper
Mature bottomland forest (after blizzard)	186	0	1977	Strip	South	This paper
Mature bottomland forest (1 year after blizzard)	306	0–5 (avg 0.5)	1978	Strip	South	This paper
Mature upland forest (1 year after blizzard)	81	0	1978	Strip	Piatt (C)	This paper
Mature upland forest (before blizzard)	341	0–3 (avg 0.3)	1974–1977	Strip	South	This paper
Mature upland forest (after blizzard)	91	0	1977	Strip	South	This paper
Mature upland forest (1 year after blizzard)	176	0	1978	Strip	South	This paper
Shrub area	41	2	1957–1958	Strip	South	Graber & Graber 1963

[a] C refers to the central region of Illinois, as shown on winter distribution maps, e.g., Fig. 10.

male, 6.3 g; May female, 7.4 g; three September–October females, 5.4, 6.5, and 5.8 g.

Mortality

It is difficult to imagine any mortality factor more serious than severe winter weather (see Winter Populations). Montgomery (1956) described the symptoms of DDT poisoning in ruby-crowned kinglets following spray treatment of city trees for elm disease in Elmhurst. Dyke (1961) reported the same type of mortality for the golden-crowned kinglet at Princeton.

The ruby-crown was also recorded as the prey of a saw-whet owl (Graber 1962), but in general, the specific controlling factors of kinglet populations are unknown.

LITERATURE CITED

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union, Baltimore, Maryland. 691 p.

Anderson, R. 1964. Winter survey. Bluebird 31(1):29–35.

Anonymous. 1916. Spring census and migration records for 1916. Audubon Bulletin, Spring 1916:36–48.

———. 1917. Spring census and migration record. Audubon Bulletin, Spring:45–54.

Baldwin, A. G. 1941. Autumn days afield. Audubon Bulletin 40:6–8.

Bennett, H. R. 1952. Fall migration of birds at Chicago. Wilson Bulletin 64(4):197–220.

Bent, A. C. 1949. Life histories of North American thrushes, kinglets and their allies. U.S. National Museum Bulletin 196. 454 p.

Birkenholz, D. E. 1977. 40. Oak-hickory-maple forest. American Birds 31(1):43.

Blake, E. R., and E. T. Smith. 1941. Chicago region. Audubon Magazine 43(6):570–572.

Brewer, R., and W. Hardy. 1950. Fourteenth breeding-bird census. 18. Swamp and thicket. Audubon Field Notes 4(6): 303.

Bursewicz, J. 1961. Bird studies at Robert W. Allerton Park, Central Illinois. M.S. Thesis. University of Illinois. 65 p.

Carpenter, J. R. 1935. Forest edge birds and exposures of their habitats. Wilson Bulletin 47(2):106–108.

Chaniot, G., and R. Kirby. 1955*a*. Winter bird population study. 27. Grazed stream bottomland. Audubon Field Notes 9(3):303.

———, and ———. 1955*b*. Nineteenth breeding-bird census. 4. Grazed stream bottomland. Audubon Field Notes 9(6): 413.

Clark, C. T., and M. M. Nice. 1950. William Dreuth's study of bird migration in Lincoln Park, Chicago. Chicago Academy of Sciences Special Publication 8. 43 p.

Comfort, J. E. 1954. St. Louis area. Bluebird 21(5):n.p.

Cooke, W. W. 1888. Report on bird migration in the Mississippi valley in the years 1884 and 1885. U.S. Department of Agriculture, Divisoin of Economic Ornithology Bulletin 2. 313 p.

———. 1915. The migration of North American kinglets. Bird-Lore 17(2):118–125.

Craigmile, E. 1918. Notes from Hinsdale. Audubon Bulletin, Spring and Summer:35.

Dyke, V. T. 1961. Illinois field notes—spring, 1961. Audubon Bulletin 118:7.

Eiseman, R. M., and M. C. Shank. 1962. Birds of the Chicago Navy Pier area. Audubon Bulletin 122:1–11.

Farwell, E. D. 1919. Bird observations near Chicago. (Privately printed, Chicago). 188 p.

Fawks, E. 1965. Field notes—May 1965. Audubon Bulletin 134:4.

———. 1967. Field notes. Audubon Bulletin 143:17–21.

———. 1972. Field notes. Audubon Bulletin 163:16–19.

Forbes, S. A. 1882. Notes on economic ornithology. Illinois State Horticultural Society Transactions 27:60–71.

Ford, E. R. 1932. Chicago region. Bird-Lore 34(6):404–405.

———. 1956. Birds of the Chicago region. Chicago Academy of Sciences Special Publication 12. 117 p.

———, C. C. Sanborn, and C. B. Coursen. 1934. Birds of the Chicago region. Chicago Academy of Sciences Program of Activities 5(2–3):17–76.

Friedmann, H. 1963. Host relations of the parasitic cowbirds. U.S. National Museum Bulletin 233. 276 p.

Gates, F. C. 1911. Summer bird life in the vicinity of Havana, Illinois, in its relation to the prominent plant associations. Wilson Bulletin 23(1):1–27.

Gault, B. T. 1901*a*. February and March bird-life at Glen Ellyn (near Chicago), Illinois. Bird-Lore 3(1):26–27.

———. 1901*b*. October and November bird-life at Glen Ellyn (near Chicago), Illinois. Bird-Lore 3 (5):168–170.

———. [1922.] Check list of the birds of Illinois. Illinois Audubon Society, Chicago. 80 p.

George, W. G. 1968. Check list of birds of southern Illinois, 1968. Southern Illinois University, Carbondale. Mimeographed. 28 p.

Graber, J. W., and R. R. Graber. 1979. Severe winter weather and bird populations in southern Illinois. Wilson Bulletin 91 (1):88–103.

———, ———, and E. L. Kirk. 1977. Illinois birds: Picidae. Illinois Natural History Survey Biological Notes 102. 73 p.

———, ———, and ———. 1978. Illinois birds: Ciconiiformes. Illinois Natural History Survey Biological Notes 109. 80 p.

Graber, R. R. 1962. Food and oxygen consumption in three species of owls (Strigidae). Condor 64(6):473–487.

———. 1968. Nocturnal migration in Illinois—different points of view. Wilson Bulletin 80(1):36–71.

———, and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906–1909 and 1956–1958. Illinois Natural History Survey Bulletin 28(3):383–528.

Greer, T. R. 1923. Brief notes on the blue-gray gnatcatcher. Oologist 40(8):130–131.

Hess, I. E. 1910. One hundred breeding birds of an Illinois ten-mile radius. Auk 27 (1):19–32.

Hundley, M., C. Scherer, and V. S. Shaw. 1968. Winter bird population study. 26. Shrubby field and lake. Audubon Field Notes 22(3):492.

Hunter, J. 1969. The gnatcatchers' nest. The Living Museum (Illinois State Museum Monthly) 31(3):103.

Jones, S. P. 1935. St. Louis region. Bird-Lore 37(6):470.

———. 1940. St. Louis region. Bird-Lore 42(6):576–577.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinios. Condor 70(4):348–357.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecological Monographs 14(1):67–106.

———. 1948*a*. Winter bird-population study. 1. Oak-maple forest and forest edge. Audubon Field Notes 2(3):151–152.

———. 1948*b*. Twelfth breeding-bird census. 10. Oak-maple forest and edge. Audubon Field Notes 2(6):232–233.

———, and J. M. Edgington. 1977. Fortieth breeding bird census. 41. Oak-maple forest and edge. American Birds 31(1):43–44.

———, D. James, and C. Weise. 1953. Winter bird population study. 20. Oak-maple forest and forest edge. Audubon Field Notes 7(3):245.

Kirby, R., and G. Chaniot, Jr. 1957. Winter bird population study. 16. Grazed stream bottomland. Audubon Field Notes 11(3):301.

Kleen, V. M. 1973. The '73 spring count. Illinois Audubon Bulletin 166:2–12.

———. 1974. The '74 spring count. Illinois Audubon Bulletin 170:3–11.

———. 1975*a*. The '75 spring count. Illinois Audubon Bulletin 174:12–19.

———. 1975*b*. Field notes. Spring migration. Illinois Audubon Bulletin 174:28–38.

———. 1976. The '76 spring bird count. Illinois Audubon Bulletin 179:4–13.

———. 1977. The '77 spring bird count. Illinois Audubon Bulletin 182:2–12.

———. 1978. Middlewestern prairie region. American Birds 32(2):210–215.

Miller, D. E., and W. B. Miller. 1972. Winter bird-population study. 54. Suburban woodlot. American Birds 26(3): 686–687.

Montague, A. C. 1950. Winter bird-population study. 12. Bottomland deciduous forest. Audubon Field Notes 4(3):225–226.

———. 1953. Winter bird-population study. 21. Bottomland deciduous forest. Audubon Field Notes 7(3):246.

Montgomery, A. E. 1956. Bird mortality in Elmhurst. Audubon Bulletin 99:1–3.

Morrison, M., and B. Peterjohn. 1977. Fortieth breeding bird census. 42. Upland deciduous forest. American Birds 31(1): 44.

Musselman, T. E. 1930. Report for central western Illinois. Audubon Bulletin 20:20–22.

———. 1931. The 1930 season at Quincy. Audubon Bulletin 21:29–31.

———. 1934–1935. 1934 nature diary. Audubon Bulletin 24–25:27–35.

Needham, J. G. 1909. Kinglets captured by burdocks. Bird-Lore 11(6):261–262.

Nelson, E. W. 1876–1877. Birds of north-eastern Illinois. Essex Institute Bulletin 8(9–12):90–155.

———. 1877. Notes upon birds observed in southern Illinois between July 17 and September 4, 1875. Essex Institute Bulletin 9:32–65.

Nolan, V. 1955. Middlewestern prairie region. Audubon Field Notes 9(4):333–335.

———. 1956*a*. Middlewestern prairie region. Audubon Field Notes 10(3):254–256.

———. 1956*b*. Middlewestern prairie region. Audubon Field Notes 10(1):27–29.

———. 1958. Middlewestern prairie region. Audubon Field Notes 12(1):33–36.

Patterson, A. J. 1920. Normal. Audubon Bulletin, Spring: 42–43.

Peattie, D. C. 1938. Spring song at the grove. Chicago Naturalist 1(1):3–9.

Petersen, P. C. 1959. TV tower mortality in western Illinois. Audubon Bulletin 112:14–15.

Ridgway, R. 1874. Catalogue of the birds ascertained to occur in Illinois. Lyceum of Natural History of New York Annals 10:364–394.

———. 1887. List of birds found breeding within corporate limits of Mt. Carmel, Illinois. Ridgway Ornithological Club Bulletin 2:26–35.

———. 1889. The ornithology of Illinois. Vol. I. Illinois State Laboratory of Natural History. Reprinted 1913, Pantagraph Printing and Stationery Company, Bloomington, Ill. 520 p. + 32 plates.

———. 1904. Birds of Middle and North America. U.S. National Museum Bulletin 50. Part 3:716–720.

Roberts, G. R. 1921. Lake Forest. Audubon Bulletin, Fall 1921:38–39.

———. 1922. Seven years of a food shelf. Audubon Bulletin, Spring 1922:7–9.

Robertson, W., Jr. 1944. Audubon Magazine's eighth breeding-bird census. 14. Upland oak-hickory forest with pond. Audubon Magazine 46(5):19 (Supplement).

Sanborn, C. C. 1921. The season. Chicago region. Bird-Lore 23(5):251–252.

———. 1922. Recent notes from an old collecting ground in north-eastern Illinois. Auk 39(3):367–373.

Schafer, J. J. 1917–1918. The fall migration. Audubon Bulletin, Winter, 1917–1918:40–43.

Seets, J. W., and H. D. Bohlen. 1977. Comparative mortality of birds at television towers in central Illinois. Wilson Bulletin 89(3):422–433.

Shaw, V. S. 1958. Winter bird-population study. 13. Shrubby field and lake. Audubon Field Notes 12(3):312–313.

———. 1962. Winter bird-population study. 17. Shrubby field and lake. Audubon Field Notes 16(3):374.

———, C. Scherer, W. Bridges, and M. Hundley. 1956. Winter bird-population study. 25. Shrubby field and forest edge. Audubon Field Notes 10(3):297.

———, and P. M. Stine. 1955. Winter bird population study. 29. Shrubby field and forest edge. Audubon Field Notes 9(3):304.

Smith, F. 1930. Records of spring migration of birds at Urbana, Illinois, 1903–1922. Illinois State Natural History Survey Bulletin 19 (2) :105–117.

Snyder, D., C. Bonney, and W. B. Robertson. 1948. Twelfth breeding-bird census. 15. Deciduous flood-plain forest. Audubon Field Notes 2(6):237.

Swink, F. [1965.] Birds of Morton Arboretum. Privately printed. 33 p.

Van Duzer, E. 1920. Notes from Rockford. Audubon Bulletin, Fall 1920:24.

Wasson, I. B., and M. Shawvan. 1953. Hawk migration over Thatcher Woods. Audubon Bulletin 88:1–2.

Widmann, O. 1907. A preliminary catalog of the birds of Missouri. Academy of Science of St. Louis Transactions 17(1). 288 p.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55(5):1017–1027.

Woodruff, F. M. 1907. The birds of the Chicago area. Chicago Academy of Sciences Natural History Survey Bulletin 6. 221 p.

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Biology

MONITORING THE SEASONAL APPEARANCE AND DENSITY OF THE BLACK CUTWORM WITH A VIRGIN FEMALE TRAP

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Lynn Pautler, William G. Ruesink,
Hans E. Hummel, and William H. Luckmann

The life history of the black cutworm, *Agrotis ipsilon* (Huf.), (BCW) is not fully known for the north-central United States where the cutworm in the destructive larval stage attacks seedling corn during May and early June. The origin of these larvae continues to be the subject of debate. Puttler et al. (1973) suggested that the damaging larvae overwinter, but information based on developmental thresholds and temperature-dependent development times (Luckmann et al. 1976) suggested they could arise from eggs laid in the spring.

This study was undertaken to develop and test a method for early season detection of BCW adults and to determine whether eggs laid at the time of the first flight could produce 3rd instar larvae by the time seedling corn is present. Swier et al. (1976) demonstrated that virgin female BCW would attract male BCW to sticky traps, and previous investigators have successfully used similar traps to study other insect populations (Swailes et al. 1975, Wong et al. 1972). A sticky trap baited with virgin female BCW was evaluated throughout the cropping season along with a black light trap to determine which method was the better indicator of adult BCW presence and density.

In order to compare catches in the black light and the virgin female traps it was desirable to find a field location and situation where both traps were highly effective at indicating adult numbers during the entire season. After preliminary investigation, an abandoned orchard in Urbana, Illinois, was chosen as a suitable place for a black light trap. The area was in permanent sod, and since it was being converted from an orchard to a tree nursery, it contained some apple trees plus a diversity of other trees and shrubs. Within this area, studies were conducted to situate a virgin female trap to maximize its efficiency yet retain practicality for field use.

MATERIALS AND METHODS

Black cutworm female moths used in the traps were obtained from a laboratory colony established in December, 1976, with eggs from a female caught in a black light trap (Fig. 1) at Urbana, Illinois. Beginning in March, 1977, females captured in the black light trap were periodically introduced into the lab-

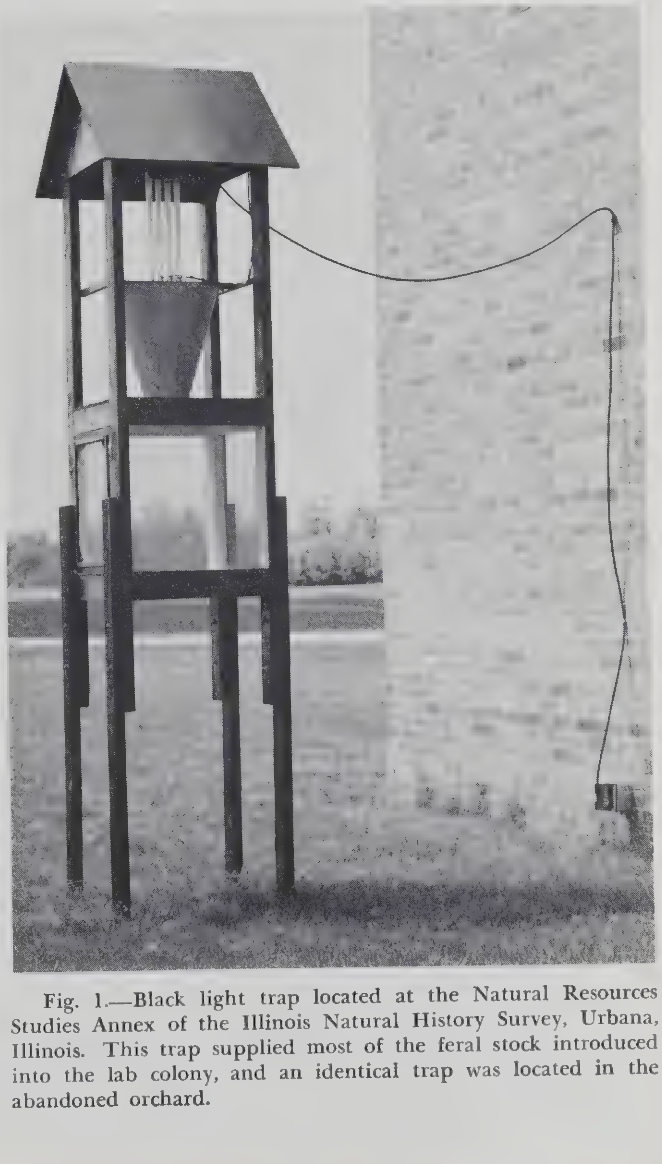

Fig. 1.—Black light trap located at the Natural Resources Studies Annex of the Illinois Natural History Survey, Urbana, Illinois. This trap supplied most of the feral stock introduced into the lab colony, and an identical trap was located in the abandoned orchard.

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oratory culture to assure that the colony was never more than one generation removed from feral stock. The procedure for culturing was similar to that described by Reese et al. (1972).

The virgin female trap was modified from a design described by Wong et al. (1972). The base and roof platform were constructed with 1.27-cm plywood and waterproofed with a clear polyurethane coating. Both platforms were expanded to squares of 60-cm sides. Tack Trap, a product of Animal Repellent, Inc., Griffin, Georgia, was applied to the upper surface of the lower platform and to the two lateral hardware cloth screens and wooden supports. The Tack Trap was changed once a week due to a build-up of other insects (mainly Diptera) and debris. Two 3-day-old females were placed within a disposable 1-pint cylindrical paper Fonda carton from Bush Brothers, Inc., Champaign, Illinois, in which the top and bottom were replaced with 0.75-mm mesh nylon screening. The carton was positioned laterally in the center of the trap and held in place by a strap of metal plumbers' tape which was fastened to the under surface of the roof (Fig. 2). A hole cut in the side of the paper carton accommodated a vial containing 10-percent honey water. At least twice a week the carton was replaced with a new one containing fresh females depending on the longevity of the females and if they were calling as indicated by males caught.

Two height-comparison tests were completed; the first was done in conjunction with a study on locational effects on catches. The first test compared virgin female traps placed on the soil surface, and at 1.0, 1.5, and 2.0 m above ground. The traps were positioned at different locations (Table 1) and were spaced at least 50 m apart and each was at least 50 m from the orchard black light. The trap height was changed randomly at each location once a week. To facilitate an easy adjustment to the desired height, metal pipes (0.95 cm inside diameter) were attached to traps and inserted into larger metal pipes (1.90 cm inside diameter) embedded 1 m in the ground. The trap in the tree was hung by rope so that it could be lowered or raised easily. The test consisted of six replicates, each replicate representing a week of daily examinations of each trap.

The second test compared heights at 1.0, 1.5, 2.0, 3.0, and 4.0 m. Because of the difficulty of maneuvering the taller heights these traps remained at their initial height location for the duration of the test. The 3-m trap rested on the peak of the roof of a small building, while the 4-m trap hung from an isolated mature apple tree. The test consisted of three replicates of one week per replication. Traps were checked daily for BCW males.

The primary virgin female trap was positioned at a height of 2 m (Fig. 3) and located at one edge of a sodded area containing mature apple trees and adjacent to cultivated fields used for the production of soybeans and corn. The black light trap was

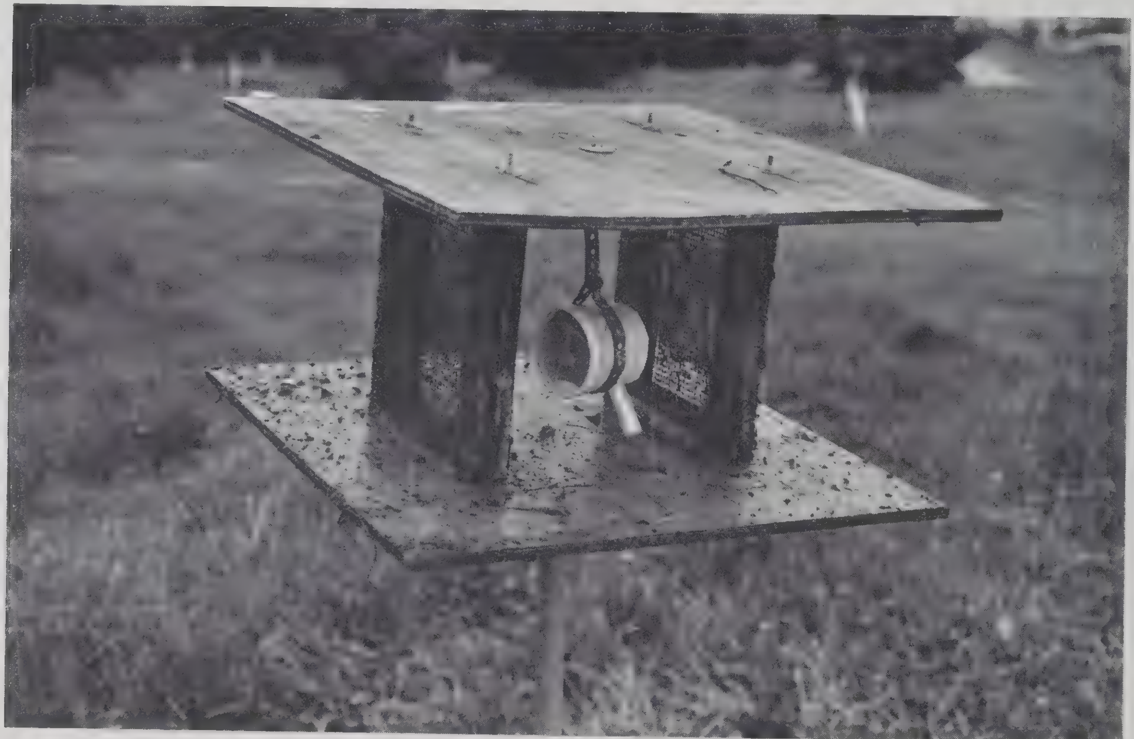

Fig. 2.—Virgin female sticky trap, showing carton for holding black cutworm females. The upper surface of the lower platform and the two lateral hardware cloth screens and supports are covered with Tack Trap.

omnidirectional and equipped with four 15-watt (43.2 cm length) black light fluorescent bulbs. It was positioned approximately 3 m above the ground and 100 m from the primary virgin female trap. There was a shed between the two traps which blocked the light of the black light from reaching the virgin female trap. The comparison began 1 March, and traps were checked daily through 7 November 1977.

The temperature records needed to calculate centigrade-degree-day development and other weather information were obtained from the Illinois State Water Survey, Urbana. Developmental threshold and rates of development for each stage of the BCW were taken from Luckmann et al. (1976). Centigrade-degree-days were calculated from the daily temperature, using the methods of Arnold (1974).

RESULTS AND DISCUSSION

Trap Height and Location

A steady increase in male BCW catches was observed with increasing trap heights. This trend was shown by both tests 1 and 2 which were run at different times during the season (Fig. 3). The lines in Fig. 3 representing these tests on trap heights illustrate clearly the relation, except for a dip at 1.5 m in test 2. Swier et al. (1976) captured the most BCW males at 1.5 m above the soil surface and found a significant drop in catches at 3.1 m. Contrary to his findings, mean catch was higher for 2, 3, and 4 m in this study (Fig. 3). However, this study was conducted in an orchard where some vegetation was as high as 10 m. Swier's work was done next to an alfalfa field where foliage was 0.46 m high. Saario et al. (1970) studied trap elevation in relation to the type of vegetation associated with a virgin female cabbage looper, *Trichoplusia ni*, sticky trap. They found more males were captured by a trap at an elevation of 2 m above the soil surface in a broccoli planting than at other heights. Average plant height in the field was 1–1.3 m, whereas, traps placed on the trunks of citrus or eucalyptus trees tended to have increased efficiency at an elevation of 4 m as compared with 1 m and 2 m. Saario and colleagues have suggested that the horizontal surface produced by the top of vegetation in a broccoli field (or an alfalfa field) may provide visual orientation for the flying males. Likewise, in an orchard area the trees may act as a visual stimulus for pheromone orientation. Thus, males would fly higher in a wooded area as compared to a flat field situation.

Due to the difficulty of maneuvering traps to higher elevations no attempt was made to find the height at which moth catch in the orchard would be greatest. The purpose of these tests was to find a height that would be practical for field use and would reliably indicate adult numbers during the entire season. The 2-m trap caught the most moths in early spring and was outperformed by only the 4-m trap later in the summer (Fig. 3). Also the trap at this height was easier to manipulate than one at 3 or 4 m. Thus, the 2-m height was used as the trap height for the seasonal comparison.

The density of vegetation surrounding a trap (within 5–10 m) affects trap efficiency (Table 1). The trap which performed poorly was located in the midst

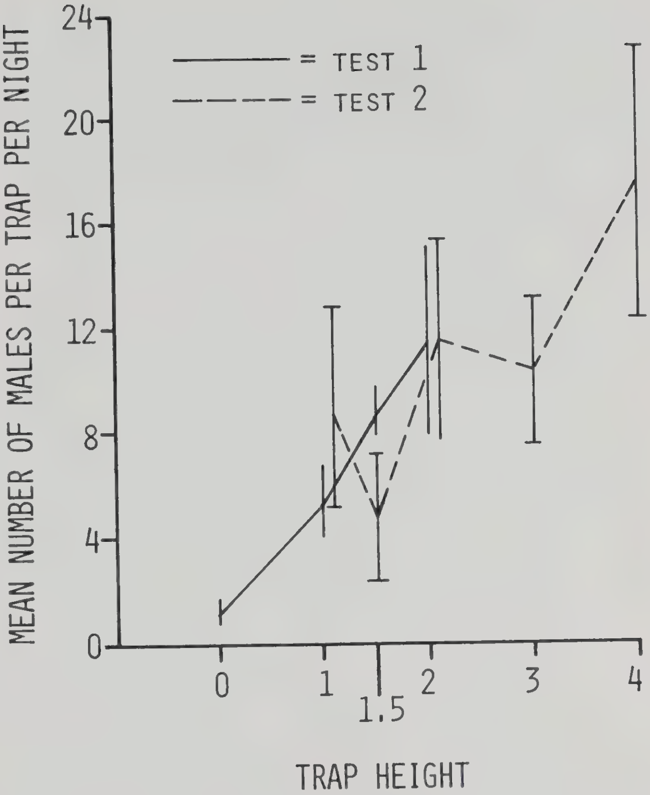

Fig. 3.—The efficiency at various heights of a sticky trap baited with virgin female black cutworms. Mean of 0 height is significantly different at $P = 0.001$ level from other heights.
Vertical lines = ± SE of mean.
Test 1—Total males captured = 1,128
20 April–2 June 1977.
Test 2—Total males captured = 1,062
14 June–6 July 1977.

TABLE 1.—Effects of location on the mean number of black cutworm males caught by a virgin female sticky trap.

Trap location[a]	Mean No. of BCW males[b c] caught/night
1	3.25 a
2	6.40 a b
3	7.25 a b
4	12.28 b

[a] Trap location 1 = trap surrounded by dense small trees and shrubs (3 m)
2 = surrounded by trees (10 m)
3 = outskirts of orchard next to soybean and cornfields
4 = hung from tree limb in open vegetation

[b] Mean separation by Duncan's NMR test. Mean in column followed by same letter not significantly different ($P = 0.05$).

[c] Mean no. is calculated from data for 32 nights.

of low shrubs and trees (2–3 m) perhaps impeding pheromone dispersal or obstructing flight. This is consistent with the finding of Saario et al. (1970) who found decreased efficiency with traps baited with virgin female cabbage loopers located in the midst of foliage. The other trap locations were surrounded by vegetation but not as dense as the low shrubs and trees.

Spring Appearance

The first BCW was caught on the night of 14 March and the second moth on the night of 15 March 1977. These first two males were found in a virgin female trap resting on the sodded surface in the orchard. From their positions away from the edge of the sticky surface it was evident that the males flew into this trap. The moths were in mint condition and easily identifiable; body scales were intact, giving the appearance of newly emerged males. These moths have been preserved and are on deposit in the permanent entomology collection of the Illinois Natural History Survey. The earliest date that the presence of BCW adults had been recorded by the black light over several years was 28 March.

The daily temperatures during the week prior to the first catches were warm, averaging 12.5°C. The temperatures on the 14th and 15th had highs of 20.6°C and 21.2°C and lows of 2.2°C and 5.6°C, respectively. There were southerly winds of up to 4.3 m/s every day during the week preceding 15 March.

No more BCW moths were captured until 27 March when the 2-m virgin female trap attracted two males. During the week prior to this date there had been a steady southerly wind at approximately 3 m/s. Fourteen males were captured in the 2-m trap on the night of 28 March. During that day there was a rainstorm with strong winds from the south up to 6.9 m/s and the daily temperature reached a high of 17.2°C and a low of 12.8°C. During 25–31 March, 1–7 April, and 8–14 April, the 2-m virgin female trap captured 24, 37, and 26 moths, respectively. The black light trap caught three males and one female, one female, and one male, respectively, during the same periods (Fig. 4).

Using 10.4°C as a developmental threshold, 9 centigrade-degree-days had accumulated at Urbana between 1 January and 14 March 1977. Only 30 centigrade-degree-days had accumulated prior to the first peak of males during the first week of April. If these early moths overwintered at Urbana, they must have done so as mature pupae. Temperatures and centigrade-degree-day accumulation were sufficient to activate a local population. However, there were strong southerly winds in March and April which may have brought these moths to central Illinois from more southerly areas.

Seedling corn damaged by 3rd and 4th instar BCW larvae was found in a field near the study area on 11 May. Centigrade-degree-day accumulation from 1 April to 11 May was 210, an amount sufficient for development from oviposition to 3rd and 4th instar (Luckmann et al. 1976). It is not likely that the larvae which damaged corn at Urbana on 11 May overwintered as early instar larvae or eggs, and it seems more probable that they were the progeny of the adults flying very early in the season. The fact that the early males were attracted to the virgin females demonstrates sexual activity, and since two females were captured in the black light trap in March and early April, mating and oviposition could have occurred during this early season flight (Fig. 4).

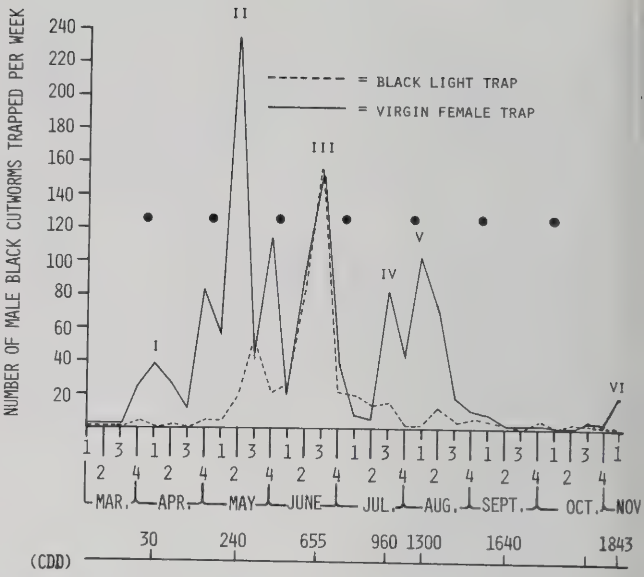

Fig. 4.—The seasonal collection of male black cutworm moths by a black light trap and a sticky trap baited with virgin female black cutworms during 1977 in an orchard area being converted into a tree nursery at Urbana, Illinois. The black dots represent the full moons and CDD are the accumulated centigrade-degree-days (base 10.4°C).

Efficiency of the Black Light

For the entire season 2.6 times more males were captured by the trap containing virgin females than by the black light. More importantly it attracted 6 times more males during March through May. The black light failed to detect the earliest adult BCW or reflect the density of the early spring flight in late March and early April.

During mid-June the black light and the virgin female trap did have identical peaks (Fig. 4). An environmental factor may have inhibited the moths' attractancy to a black light during other peaks. Williams et al. (1956) observed reductions in light trap captures during periods of a full moon. He suggested the moonlight competed with the light from the traps, reducing trap efficiency. Agee et al. (1972)

noted that *Heliothis zea* catches increased in the period of the new moon and decreased sharply 2–3 days prior to the full moon and 1–2 days thereafter in a black light. A similar trend was previously observed for BCW, but a significant difference between new and full moon catches could not be demonstrated (Hanna & Atraies 1970). In our study, black light catches were very low at every full moon (Fig. 4), even when the virgin female trap was catching high numbers.

Generations per Season

For the codling moth, *Laspeyresia pomonella,* three peaks of male catches in pheromone traps were interpreted as corresponding to the emergence of three generations (Batiste et al. 1973, Metcalf 1975). Miyahara et al. (1977) detected five generations of *Spodoptera litura* using a virgin female trap of that species. Thus, sex pheromone traps appear to be good indicators of activity in the field.

Only 210 degree-days accumulated between peak I and peak II in Fig. 4, while according to Luckmann et al. (1976) an average of 643 is required for a generation. Thus, the second flight of moths which occurred in early May could not have emerged as progeny from the flight which occurred in early April.

There is sufficient degree-day accumulation for development of a generation between peaks I and III and again between peaks III and V. Also, there is sufficient temperature accumulation for a generation between II and IV. The moths beginning to appear at VI could have come from IV or V and may be a merging of the two populations. Because temperatures were very cold after 7 November, the study was terminated at that time.

The data presented in Fig. 4 depict events only for 1977. We do not know whether two overlapping populations always occur and whether the number of generations per year is consistent, but the results presented here are based on events that did occur and which contribute to our knowledge about this important pest.

LITERATURE CITED

Agee, H. R., J. C. Webb, and H. M. Taft. 1972. Activity of bollworm moths influenced by the full moon. Environmental Entomology 1(3):384–385.

Arnold, C. Y. 1974. Predicting stages of sweet corn *(Zea mays* L.) development. American Society of Horticultural Science Journal 99:501–505.

Batiste, W. C., A. Berlowitz, W. H. Olson, J. E. DeTar, and J. L. Joos. 1973. Codling moth: Estimating time of first egg hatch in the field—A supplement to sex-attractant traps in integrated control. Environmental Entomology 2: 387–391.

Hanna, H. M., and I. F. Atraies. 1970. The effect of moonlight on certain nocturnal Lepid. Societe Entomologique D'Egypte Bulletin 53:7–12.

Luckmann, W. H., J. T. Shaw, D. W. Sherrod, and W. G. Ruesink. 1976. Developmental rate of the black cutworm. Journal of Economic Entomology 69:386–388.

Metcalf, R. L. 1975. Insecticides in pest management. Pages 235–273 *in* R. L. Metcalf and W. H. Luckmann, eds., Introduction to Insect Pest Management. New York: Wiley-Interscience. 587 p.

Miyahara, Y., M. Shimazu, and T. Wada. 1977. Seasonal occurrence of *Spodoptera litura* (F.) as measured by a virgin female trap. Japanese Journal of Applied Entomology and Zoology 21:59–65.

Puttler, B., R. E. Sechriest, and D. M. Daugherty, Jr. 1973. *Hexamermis arvalis* parasitizing *Agrotis ipsilon* in corn and the origin of the pest infestation. Environmental Entomology 2:963–964.

Reese, J. C., L. M. English, T. R. Yonke, and M. L. Fairfield. 1972. A method for rearing black cutworms. Journal of Economic Entomology 65:1047–1050.

Saario, C. A., H. H. Shorey, and L. K. Gaston. 1970. Sex pheromones of noctuid moths. XIX. Effect of environmental and seasonal factors on captures of males of *Trichoplusia ni* in pheromone-baited traps. Entomological Society of America Annals 63:667–671.

Swailes, G. E., D. L. Struble, and N. D. Holmes. 1975. Use of traps baited wtih virgin females for field observations on the bertha armyworm (Lepidoptera: Noctuidae). Canadian Entomologist 107:781–784.

Swier, S. R., R. W. Rings, and G. J. Musick. 1976. Reproductive behavior of the black cutworm, *Agrotis ipsilon.* Entomological Society of America Annals 69:546–550.

Williams, C. B., B. P. Singh, and S. El Ziady. 1956. An investigation into possible effects of moonlight on the activity of insects in the field. Royal Entomological Society of London Proceedings 31:135–144.

Wong, T. T. Y., H. Kamasaki, R. E. Dolphin, D. G. Davis, T. E. Mouin, D. F. Ralston, and J. E. Burnside. 1972. Mass trapping of male lesser peachtree borer moths with virgin-female traps on Washington Island, Wisconsin, 1970. Journal of Economic Entomology 65:1034–1039.

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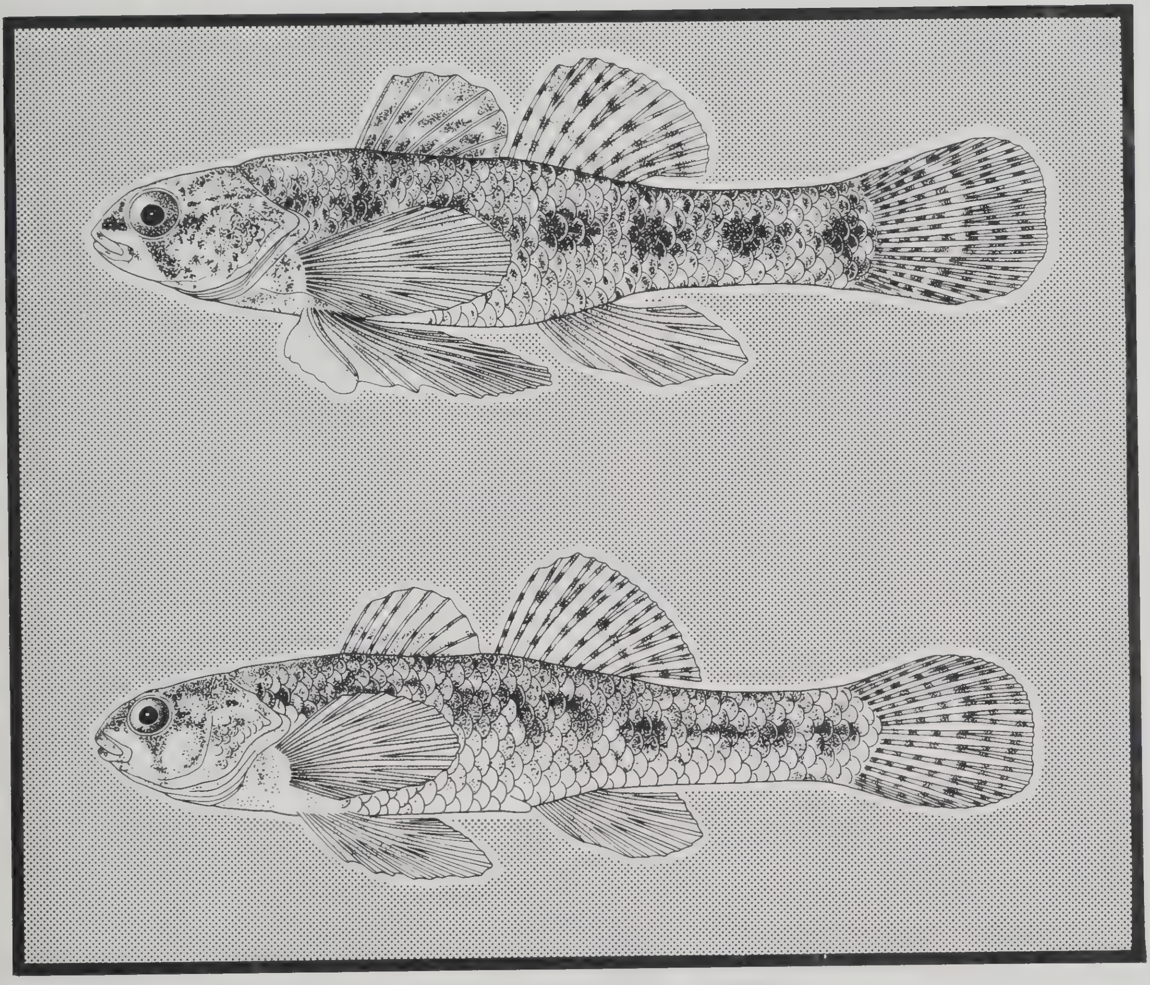
Biology

HE LIFE HISTORY OF THE LEAST DARTER, *Etheostoma microperca*, IN THE IROQUOIS RIVER, ILLINOIS

BROOKS M. BURR and LAWRENCE M. PAGE



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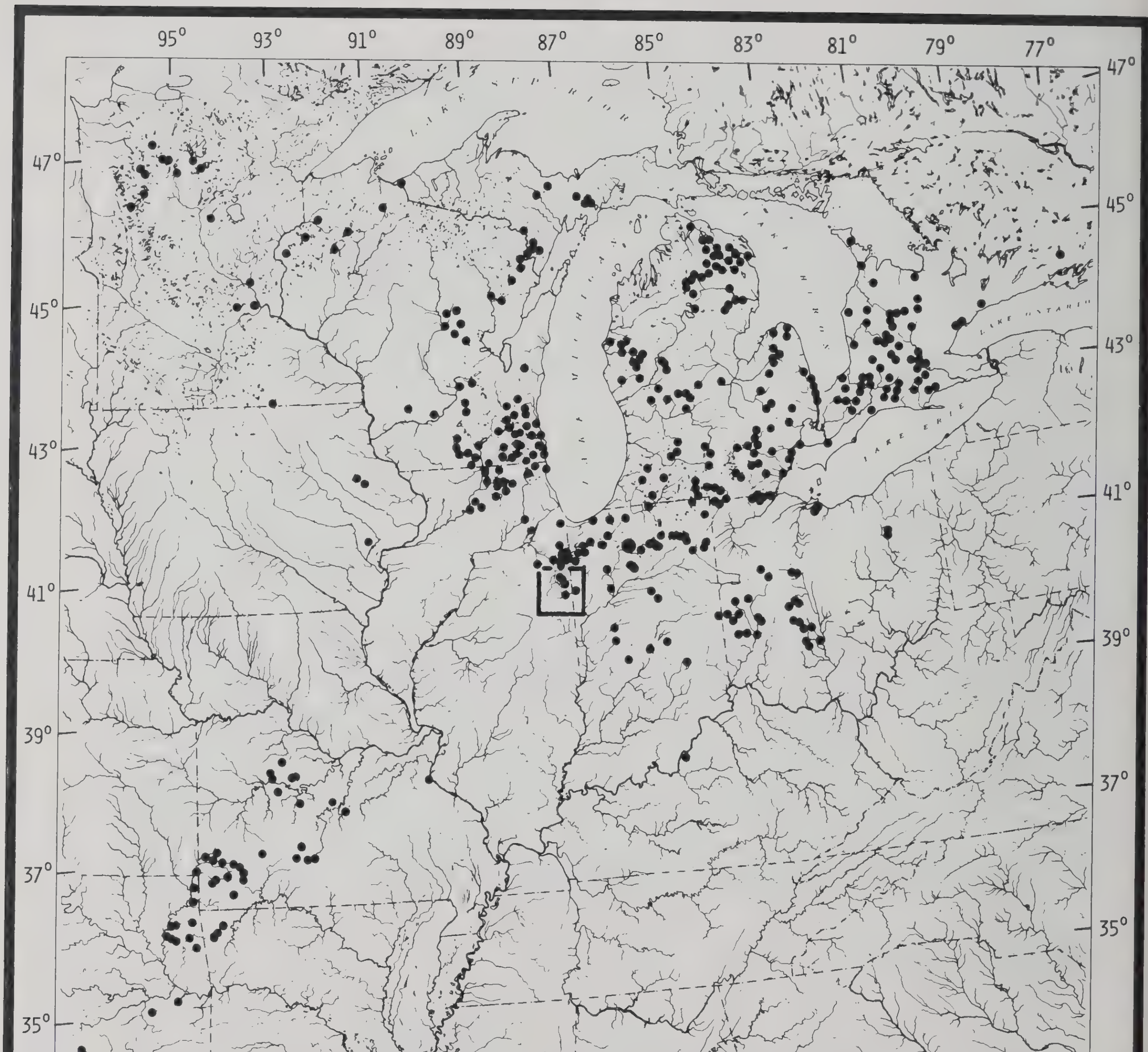

Fig. 1.—The distribution of *Etheostoma microperca*. Questionable records were not plotted. The study area is enclosed within the square.

THE LIFE HISTORY OF THE LEAST DARTER, *ETHEOSTOMA MICROPERCA*, IN THE IROQUOIS RIVER, ILLINOIS

Brooks M. Burr and Lawrence M. Page

This report on *Etheostoma microperca* in a small tributary of the Iroquois River is the second life history report on the subgenus *Microperca* in Illinois. The first was on *E. proeliare* (Burr & Page 1978). Included here are comparisons of the two Illinois species and *E. fonticola,* a third member of the subgenus recently studied by Schenck & Whiteside (1976, 1977*a*, 1977*b*).

Etheostoma microperca was described by Putnam in 1863 (as *Microperca punctulata)* from specimens collected from localities in Michigan, Wisconsin, Illinois, and Alabama. Those from Alabama presumably represented the closely related but then unnamed *E. proeliare.* The range of *E. microperca* (Fig. 1) extends from Moira River in northeast Ontario, through much of the Great Lakes drainage, northwest to the Red River of the North in Minnesota, and south through the middle Ohio River Valley. Disjunct populations occur in the Ozark Uplands and in the Blue River, Oklahoma. A detailed morphological description and comparisons with related species are found in Burr (1978).

We are indebted to John A. Boyd, Patti A. Burr, and Michael A. Morris for aid in collecting specimens; to Edward A. Lisowski, John K. Bouseman, José A. Mari Mutt, and Donald W. Webb, all presently or formerly of the Illinois Natural History Survey (INHS), for identification of stomach contents; to David F. Oetinger and William L. Current, University of Nebraska-Lincoln, for identification of parasites; and to Philip W. Smith, Illinois Natural History Survey, for counsel and advice.

We are grateful to the following curators and their institutions (abbreviations are used in the text and Table 2) for granting specimen loans, laboratory space, and other courtesies: Branley A. Branson, Eastern Kentucky University (EKU); Frank B. Cross, University of Kansas (KU); Max A. Nickerson, Milwaukee Public Museum (MPM); Neil H. Douglas, Northeast Louisiana University (NLU); Loren G. Hill, University of Oklahoma (OAM); Ted M. Cavender, Ohio State University Museum (OSM); E. J. Crossman, Royal Ontario Museum (ROM); Carter R. Gilbert, University of Florida, Florida State Museum (UF); Reeve M. Bailey and Robert R. Miller, University of Michigan Museum of Zoology (UMMZ); Albert P. Blair (APB) and Hague Lindsay, University of Tulsa (UTULSAC); and Wayne C. Starnes (WCS), University of Tennessee.

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STUDY AREA

Etheostoma microperca occurs sporadically in northern Illinois and is common at certain localities in the Rock, Fox, and Kankakee river systems. A small, unnamed tributary of Iroquois River (Kankakee system) northeast of Watseka in Iroquois County was selected for the life history study. The Iroquois River lies within the area of Wisconsinan Drift, and the watershed was originally sandy marsh (especially in Indiana) and tall-grass prairie (Forbes & Richardson 1920:xxxviii) but is now mostly farmland.

The tributary in which *E. microperca* was studied is a short (6 km long) direct tributary of the Iroquois River, meandering through cultivated fields upstream and forested land downstream. The study area (Fig. 2), at a bridge 6 km northeast of Watseka, is surrounded by cultivated fields. One small, rock riffle and a few mud-bottom pools are present, but the rest of the study area is a sinuous channel of nearly uniform width (0.5–1.0 m), depth (< 0.5 m), and substrate (mixed sand and silt). The water current is slow. Stream banks are grassy and devoid of trees. Water temperatures varied during the study period from 4°C in February to 24°C in July. In summer and fall some rooted vegetation was present, and filamentous algae dominated large stretches of the stream. At this site and for a moderate distance upstream and downstream *E. microperca* was the most common fish.

Seventy-three species of fishes occur in the Illinois portion of the Kankakee River system. At the study area the most common, in addition to *E. microperca,* are *Pimephales notatus, Semotilus atromaculatus, No-*

This paper is published by authority of the State of Illinois, and is a contribution from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Brooks M. Burr, formerly a Research Assistant at the Survey, is Assistant Professor, Department of Zoology, Southern Illinois University, Carbondale. Dr. Lawrence M. Page is an Associate Taxonomist at the Survey.

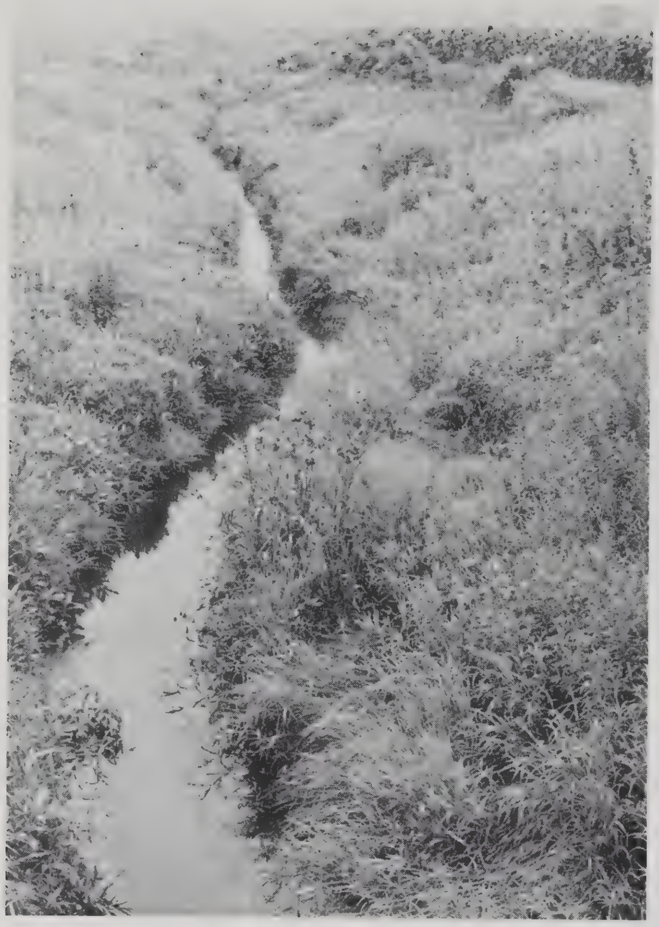

Fig. 2.—The *Etheostoma microperca* life history study site, an unnamed tributary of the Iroquois River, 6 km northeast of Watseka, Iroquois County, Illinois. Photo taken 3 July 1978.

tropis stramineus, Campostoma anomalum, Lepomis cyanellus, Fundulus notatus, and *Etheostoma nigrum.*

METHODS

Methods of study were those employed by Page (1974:4–5) except as noted below. Observations and minnow-seine collections were made at approximately monthly intervals from 5 August 1975 to 27 September 1976. Additional data on reproduction were acquired on 26 March 1977 and 19 May 1977. Aging to month was done, using May, the month of the greatest breeding activity in the study area, as month zero. A total of 700 specimens was preserved and stored in 10-percent formalin.

Because the study site was physically uniform and *E. microperca* was found to be rather evenly distributed throughout, no attempts were made to sample by habitat. However, quantitative samples were made to monitor variations in the population density of *E. microperca.*

Nearly all *E. microperca* from museum collections were examined to determine probable spawning periods in other localities and other years. Indicators of spawning preparedness were the same as those listed by Burr & Page (1978:5). Specimens in a collection were considered to be in spawning condition if any of the specimens was in peak reproductive condition.

HABITAT

Adults of *E. microperca* were consistently found in submerged vegetation along overhanging grassy banks and among filamentous algae. Rarely were they found in midstream away from any vegetation. During high water they avoided strong current and were found almost exclusively in quieter water under overhanging banks. Juveniles were found in thick growths of algae at the edge of the stream.

Comparative collections made by the authors in Oklahoma, Missouri, Indiana, and Michigan indicate that the species prefers quiet waters rich in vegetation (most often filamentous algae, *Elodea, Myriophyllum,* or *Ceratophyllum)* with sand or muck bottoms. *E. microperca* is abundant in some Ozark springs, spring runs, and spring-fed creeks. In Ohio it is present in clear pothole lakes and prairie streams of low gradient with bottoms consisting of soft muck, sand, or gravel (Trautman 1957:604). The preferred habitats of *E. microperca* are heavily vegetated, low-gradient water bodies, including small to large streams and margins of lakes and vegetated springs.

REPRODUCTION

Reproductive Cycle of the Male

By early January the genital papilla of the male begins to swell noticeably, and by late March or early April it is thick and stout (Fig. 3). Testes of breeding males are greatly enlarged, opaque white, and spongy; those of nonbreeding males are small and translucent.

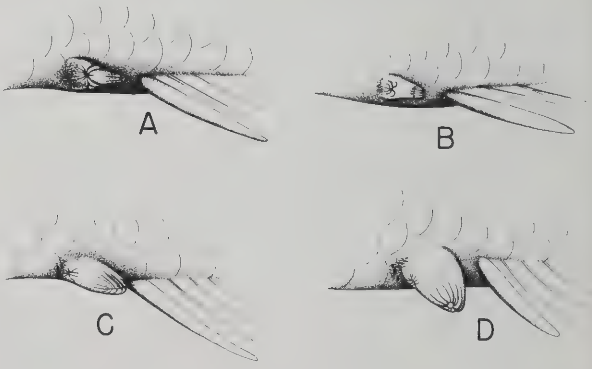

Fig. 3.—Genital papillae of *Etheostoma microperca.* A, nonbreeding male; B, breeding male; C, nonbreeding female; D, breeding female. The breeding specimens were 1 year old, collected on 23 May 1976. The nonbreeding specimens were 1+ years old, collected on 30 August 1976.

All spring-collected males—including the smallest, a 22.0-mm male collected in April—were sexually mature and thus were potential spawners. In all three species of the subgenus *Microperca* males were found to be sexually mature at 1 year.

Males began to develop lateral flaps of skin on the pelvic fins as early as late January, but it was not until mid-March that breeding colors were evident and not until April that breeding tubercles appeared. By mid-March the pelvic-fin flaps were developed nearly to their maximum, and the color of the first dorsal, anal, and pelvic fins had intensified.

From about the second week of April to the end of June, male breeding colors and structures were at their peak development (Fig. 4). The body was dark green with 8–10 intense mid-lateral black blotches interspersed with spots of metallic green. The pre-, post-, and suborbital bars were intense black. The opercle, belly, and pectoral fin bases were metallic green. The flesh overlying the top of the head and the second dorsal and caudal fins was thick and milky white. The iris of the eye was red. Distally and basally the first dorsal fin was charcoal gray; medially in each membrane was an intense red-orange spot surrounded by flecks of metallic green. The second dorsal fin had four or five charcoal gray bands; the caudal fin had six or seven charcoal gray bands. The pectoral rays were sharply outlined by melanophores. The throat, breast, and belly had large black blotches of pigment. The pelvic and anal fins were a deep red-orange.

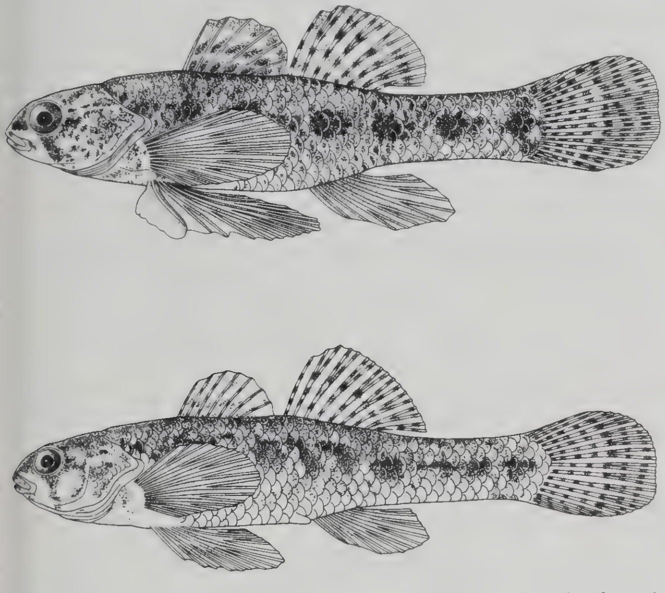

Fig. 4.—Breeding male (upper) and breeding female (lower) *Etheostoma microperca* collected in the Iroquois River on 23 May 1976. Both the male and female were 30 mm. Nuptial tuberculation is not shown. Drawings by Alice A. Prickett.

Tubercles developed on all the pelvic fin rays, and were most heavily concentrated on the distal portions of the rays. Pelvic fin flaps were developed to their maximum, with the skin greatly expanded on both sides of the pelvic spine and between pelvic rays one through three.

Winn (1958*a*, 1958*b*) indicated that during the breeding season small stationary areas about 30 cm in diameter are defended as territories by *E. microperca*. Plants are apparently used in the delimitation of territories. At the study site on 19 May 1977 agonistic encounters were observed between males, and in aquaria certain males appeared to establish territories. Pugnacious behavior was observed on numerous occasions between rival males. Evidence for the establishment of territories was not found in *E. proeliare* (Burr & Page 1978:11) or *E. fonticola* (Strawn 1956).

Reproductive Cycle of the Female

The genital papilla of the female enlarged over several months and by the spawning period was a swollen conical structure (Fig. 3) much larger than the papilla of the male. The conical shape of the female papilla of *E. microperca* is different from the bulbous and bilobed shape of the papilla of *E. proeliare* and *E. fonticola* (Burr 1978:7).

The female color and pattern (Fig. 4) changed little prior to and during the breeding period. The pelvic and anal fins became amber in color and sometimes developed a light yellow or orange cast. In a few females there was some orange in the medial portions of the first dorsal fin membranes and in the iris of the eye. The second dorsal and caudal fin bands were charcoal gray, and the pectoral fins were sharply outlined by melanophores.

Ovaries in July and August were small. From September through February ovaries were small and pink, and ova were small and white. By March, some yellow ova were discernible, and from April to June large dark-yellow ova were present. Prior to spawning the large, dark-yellow ova transformed into translucent, prominently indented eggs 0.8–1.1 mm across and with one or two large oil droplets (see Burr & Page 1978:6 for an illustration of indented eggs). Prominently indented eggs are characteristic of the three species of *Microperca*. The indentation, involving both the chorion and egg plasma membrane, disappears soon after fertilization and does not facilitate attaching eggs to the substrate nor packing eggs in the ovaries (Burr & Ellinger 1980).

All females collected from April to June had large, maturing or translucent ova and apparently would have spawned. The smallest spring-collected female was 23.2 mm and was collected 27 April 1976. In 16 females collected in April–June 1976 the number of mature ova ranged from 31 to 240 (Table 1). For these females there was no significant correlation between the number of mature ova and the standard length, nor between the number of mature ova and the adjusted body weight; for both relationships the

Table 1.—Relationship between size, age, and ovary weight of *Etheostoma microperca* females and the number of mature ova. All females were 1 year (11–13 months) old.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Month of Collection	Ovary Weight in Grams	Number of Mature (Dark Yellow or Translucent) Ova
28	0.20	April	0.04	54
28	0.27	April	0.04	62
23	0.21	May	0.05	102
24	0.18	May	0.04	92
24	0.20	May	0.06	104
25	0.19	May	0.05	84
25	0.23	May	0.09	180
26	0.24	May	0.06	112
27	0.24	May	0.07	154
28	0.24	May	0.06	101
30	0.32	May	0.08	240
30	0.32	May	0.09	174
29	0.18	June	0.04	31
29	0.33	June	0.03	78
30	0.28	June	0.03	36
30	0.29	June	0.04	106

[a] Adjusted body weight is the specimen's weight after removal of the ovaries, stomach, intestine, and liver.

correlation coefficient *(r)* was less than 0.12. The same lack of correlation was found in *E. proeliare* and is discussed by Burr & Page (1978:6–7). Because eggs are laid over a relatively large area, spawning in *E. proeliare* and *E. microperca* is likely to be interrupted; thus an accurate estimate of the number of eggs produced during the spawning season is difficult. Egg counts presented on these species and on *E. fonticola,* which lays eggs throughout the year (Schenck & Whiteside 1977*a*:367), may not be of the total numbers produced. Petravicz (1936:81) reported that a female *E. microperca* lays about 30 eggs during 1 day of spawning. Winn (1958*b*:182) who counted all ova (believing that all are normally laid in a season), reported 455–1,102 eggs laid by *E. microperca.*

From August until the spawning period, ovaries increased in size relative to the body of the female (Fig. 5). For the females examined, the relationship between the mean weight of the ovaries divided by the adjusted body weight (Y) and the month (X), with August = 1 and May (the month of the greatest spawning activity) = 10, was log Y = 0.799 + 0.158 X, with $r = 0.779$ (Fig. 5). The proportionally largest ovaries (equalling 38.9 percent of the adjusted body weight) were found in a 25-mm female collected on 23 May 1976. In the 16 females represented in Table 1, ovary-weight-to-adjusted-body-weight ratios ranged from 0.092 to 0.389 and averaged 0.230.

Spawning

At the study area *E. microperca* in breeding condition were found from April to June. Individuals transferred from the Iroquois River on 27 April 1975, 23 May 1976, 31 May 1976, and 19 May 1977 spawned in aquaria on those days and/or for a few days thereafter. Stream temperatures at the time of the capture of ripe *E. microperca* individuals ranged from 16° to 20°C; aquaria temperatures ranged from 20° to 23°C. Petravicz (1936:78) gave stream temperatures of 12°–15.5°C for ripe *E. microperca;* Winn (1958*b*: 158) listed spawning temperatures as 16°–18°C. Spawning was observed in the Iroquois River on 19 May 1977 along the shallow margins of the stream in dense beds of filamentous algae; this spawning habitat agrees with the observations of Petravicz (1936) and Winn (1958*a*, 1958*b*).

Examinations of preserved museum specimens from throughout the range of the species indicated that spawning occurs early (February–May) in the Blue River, Oklahoma, and certain Ozark streams and later (May–July) in more northern areas (Table 2). Populations of *E. microperca* that occur in or near constant-temperature springs in the Ozarks (see Niangua River, Missouri, Table 2) possibly spawn through much of the year, as does the related *E. fonticola* (Schenck & Whiteside 1977*a*:367–368) which occurs in a large constant-temperature spring in Texas. Geographic variation in spawning periods is almost certainly related to warmer water on earlier dates at more southern latitudes. In addition to the probable spawning dates listed in Table 2, the following are from published literature: May (Mich-

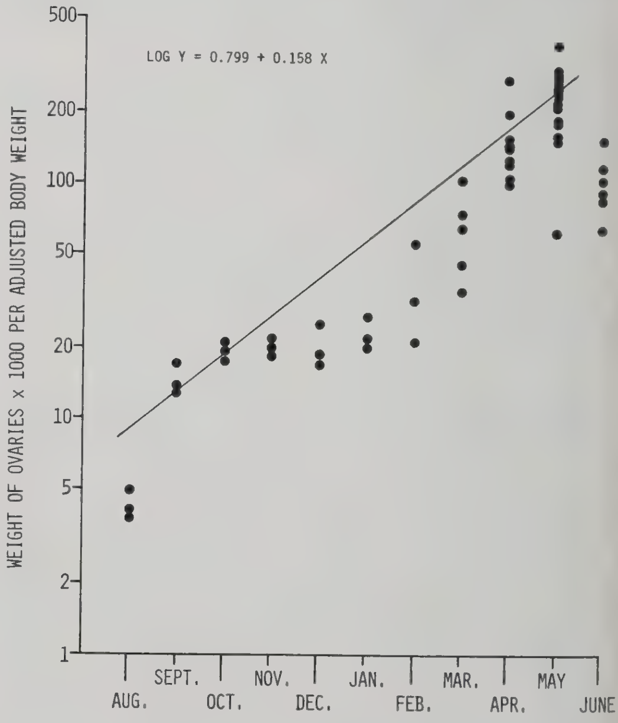

Fig. 5.—Monthly variations in ovarian weight relative to adjusted body weight of 3- to 13-month-old *Etheostoma microperca* females. The vertical axis is a logarithmic scale.

TABLE 2.—Frequency distribution by month of the collection of *Etheostoma microperca* in breeding condition from throughout the range of the species. Drainages are arranged primarily by latitude and geographic propinquity where possible. Numbers in parentheses are numbers with specimens in reproductive condition as explained under Methods. Museum collection abbreviations are given in the introduction.

Drainages	Feb.	Mar.	Apr.	May	June	July	Aug.	Collection Dates
Blue R., OK (7—EKU 614; INHS 75678; KU 12924; OAM 1597, 7157, 9158, 10015)	2	....	5	....	....	....	....	1 February–27 April
Illinois-Neosho R., OK, AR, MO (8—APB uncat; KU 10735, 10749; NLU 25892; UTULSAC 1171, 2571, 2522; WCS AK/NS1-1)	1	3	2	1	1	....	....	6 February–9 June
Gasconade R., MO (3—INHS 75828; KU 8029, 10989)	....	1	1	1	....	....	....	18 March–1 May
Sac R., MO (1—INHS 75822)		1	....	...	....	....	....	18 March
Niangua R., MO (3—INHS 75817; UMMZ 108728, 150283)	....	1	....	....	....	1	1	20 March–19 August
Great Miami R., OH (1—OSM 14249)	....	1	....	....	....	....	....	27 March
Scioto R., OH (2—OSM 22980; UMMZ 159856)	....	....	1	1	...	....	....	18 April–6 May
Kankakee-Fox R., IL, IN (10—INHS 4168, 5402, 5491, 73838; Iroquois River collections)	....	....	2	3	4	1	....	27 April–12 July
Rock R., IL, WI (4—INHS 206, 3201, 3248; MPM 7932)	....	....	....	2	2	....	....	8 May–11 June
Upper Mississippi R., MN (2—UF 21046; UMMZ 95001)	....	....	....	1	....	1	....	14 May–4 July
L. Michigan, MI, WI (10—MPM 9886; UMMZ 82012, 84222, 90033, 90123, 90380, 97950, 97994, 139002, 164398)	....	....	1	4	4	1	....	26 April–16 July
L. Huron, MI, ONT (9—UMMZ 61723, 66702, 67927, 67986, 68991, 69114, 73187, 85530; ROM 30505)	....	....	....	3	2	4	....	2 May–10 July
Thames R., ONT (4—ROM 30135, 30138, 30996; UMMZ 85567)	....	....	....	1	3	....	....	26 May–19 June
Maumee R., south L. Erie, OH, MI, ONT (10—OSM 9957; ROM 30636, 30843; UMMZ 56858, 66516, 87504, 89872, 89961, 118501, 162222)	....	....	....	5	4	1	....	2 May–21 July

igan)—Hankinson 1908:216; 26 April and 5 May (Michigan)—Petravicz 1936:78; mid-April to mid-June (Michigan)—Winn 1958*b*:165; 27 May (Michigan)—Winn 1958*a*:201; 30 June (Oklahoma)—Branson 1970: 460; May to early June (Missouri)—Pflieger 1975:323.

The first reference to spawning in *E. microperca* is that by Hankinson (1908:216) who observed breeding pairs in Walnut Lake, Michigan, with a female below and a male above in "what may have been the spawning act." Petravicz (1936) later gave a more detailed account of breeding habits of the species based on field and laboratory observations on a population in Bell Branch, Detroit, Michigan. Winn (1958*a*, 1958*b*) gave the most complete account of reproduction in *E. microperca* based on field and laboratory observations on individuals from two lakes in Washtenaw County, Michigan. Our observations of spawning in *E. microperca* agree closely with those of the above authors.

Spawning was observed at the study site at 1030 hours on 19 May 1977. Spawning in aquaria occurred at various times throughout the day and was observed on numerous occasions. Field observations agreed with those made on aquaria-held specimens. The description that follows is from laboratory observations. Males were much more active in aquaria than males of the related *E. proeliare* or *E. fonticola* (Strawn 1955:412) and constantly pursued females. They courted females by hanging vertically in midwater for several seconds while vibrating their fins vigorously. Occasionally a male mounted a female, clasped her with his pelvic fins, and bore down on her nose, head, or nape with his chin and throat as if to stimulate her. No actual "chin rubbing" was observed as in *E. proeliare* (Burr & Page 1978:8) and *E. gracile* (Braasch & Smith 1967:7).

The female selected the site of egg deposition and, with the male close behind, elevated to the site (Fig. 6). At the egg site the male mounted the back of the female, the two quivered intensely for a few seconds while curved in a loose S-shaped fashion such that the female genital papilla was on the selected spot, and 1–3 adhesive eggs were laid. The S-shaped position presumably facilitated the release of milt close to the eggs. At the instant of egg laying both the male and female always had their mouths wide open; in *E. proeliare* only the female had her mouth open at the instant of egg laying. Eggs ranged from 0.8 to 1.1 mm across and were attached to twigs, leaves, algae and the sides of the aquarium. On several occasions spawning pairs swam the depth of the water (30 cm) in the aquarium, stuck their snouts just above the water surface, and deposited eggs on the side of the aquarium.

Usually several eggs were laid at one site (e.g., a clump of twigs). In contrast to *E. proeliare, E. microperca* would perform three or four spawning acts in succession with only a brief period of rest in between. Spawning pairs of *E. proeliare* usually separated and rested up to a minute before they resumed spawning. Typically a pair would lay several eggs at one site and then move 5–15 cm from the first site and lay several more eggs. On a few occasions eggs were not laid during mounting and quivering. In an aquarium in which were placed four females and three males, 96 eggs were laid on a plastic substrate

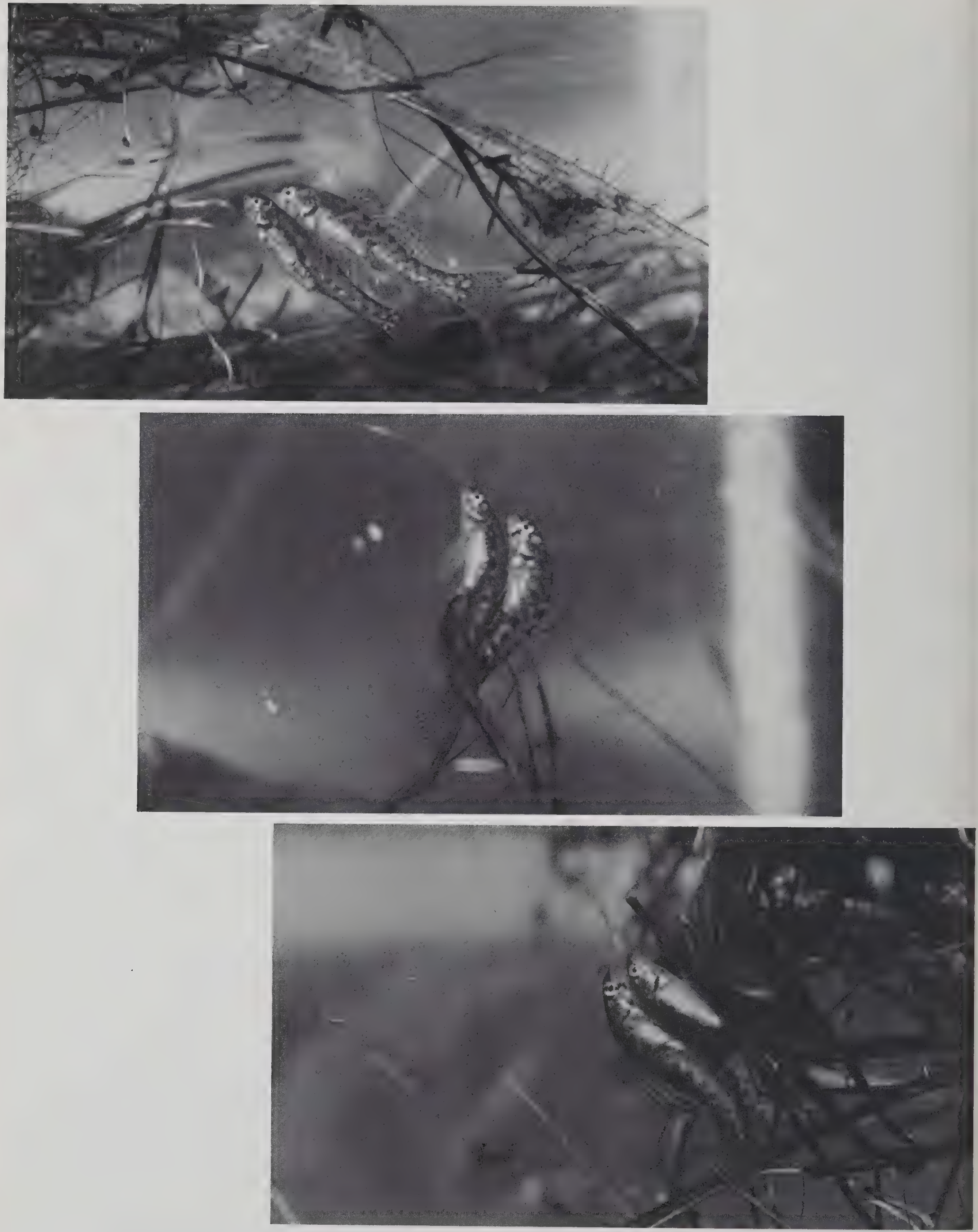

Fig. 6.—*Etheostoma microperca* spawning in aquaria. Top: Male bearing down on nape of female illustrating a typical part of courtship behavior. Middle and lower: Male and female in vertical position as egg and sperm are released on twigs. Note intensity of pigmentation in male and gaping mouths of both sexes.

and 29 eggs were found on a piece of leaf after 5 hours.

Laying eggs on the sides of aquaria and on leaves and twigs required the spawning pair to assume vertical positions. These positions were maintained by rapid vibrations of the caudal and pectoral fins. The expanded pelvic fins of the male enabled him to grip tightly the middorsum of the female. Fin positions for the two sexes were virtually identical to those described for *E. proeliare* (Burr & Page 1978:10). While the spawning position of *E. microperca* was almost always vertical, horizontal positioning during successful egg-laying was observed occasionally.

Some spawning males did not have pelvic or anal fin tubercles. The lack of tubercles on those individuals indicates that the structures are not necessary for maintenance of body contact but probably aid in the stimulation of the female.

In aquaria, males spawned with several females and often attempted to mount other males. All the males held in aquaria during the spawning season spawned. Neither sex gave any attention to the eggs after spawning. Parental care is absent in all three species of *Microperca*.

Winn (1958*b*:163–164) reported that *E. microperca* moved from the deeper portions of lakes and streams to shallow areas to spawn, and that males often arrived 1–2 weeks earlier than females. Petravicz (1936:79) stated that samples of *E. microperca* taken from mid-stream generally yielded many more females than males, but that hauls made near shore resulted in a more evenly distributed sex ratio. He concluded that females remained in deeper water until ready to spawn, at which time they entered the inshore spawning territory occupied by males. Spawning migrations were not observed at the study site because the small size and vegetated nature of the stream probably negated the need for the invasion of a new habitat.

The spawning behavior of the three species of *Microperca* is similar. Spawning position is usually vertical or inverted and male-female positioning is nearly identical. Only 1–3 eggs are laid at each spawning act (Burr & Page 1978:8, Strawn 1956:14), and egg deposition sites are much the same.

Sexual Dimorphism

Sexual dimorphism in tuberculation, pelvic fin structure, coloration, and genital papillae are discussed elsewhere in this paper and by Burr (1978:25–32). A taxonomic study of *E. microperca* from throughout its range revealed that 8 of 16 morphometric characters measured on breeding specimens showed highly significant ($P < 0.005$) sexual dimorphism (Burr 1978:51). Males had significantly longer heads, wider interorbital widths, longer postdorsal lengths, deeper caudal peduncles, and longer pelvic, pectoral, anal, and second dorsal fins. *E. proeliare* was sexually dimorphic ($P < 0.005$) for 7 out of the 16 morphometric characters measured and *E. fonticola* 5 out of the 16 (Burr 1978:48, 50).

DEVELOPMENT AND GROWTH

Eggs incubated in aquaria at 15.5°C (60°F) hatched in 264 ± 13 hours (11 days), at 20°C (67°–68°F) hatched in 181 ± 7 hours (7.5 days), and at 22°-23°C (71°–74°F) hatched in 144 ± 12 hours (6 days). Eggs incubated at 27°C (80°F) spoiled after a few days. Petravicz (1936:82) and Winn (1958*b*:182) reported hatching time at 18°–20°C (64°–67°F) to be 6.0–6.2 days.

A hatchling 3.5 mm in total length was mostly translucent but had individual melanophores on the head, yolk sac, and some of the myomeres (Fig. 7: top). The pectoral fins were larger than in other species of *Etheostoma* studied (e.g., *E. gracile*—Braasch & Smith 1967:9; species of *Catonotus*—Page 1974:11, 1975:8–9; Page & Burr 1976:8) and the tail had an unusual shape. Petravicz (1936:82) reported a hatchling 3 mm in total length. Three-day old larvae (Fig. 7:middle) averaged 4.0 mm in total length and had 10 pectoral fin rays, several caudal fin rays, and melanophores concentrated on the yolk sac remnant, head, and myomeres. At 7 days a juvenile was 4.7 mm in total length: the yolk sac had nearly disappeared, the caudal fin had many rays developed, and the pectoral fins were large (Fig. 7:bottom). The pelvic, dorsal, and anal fins had not differentiated at 7 days.

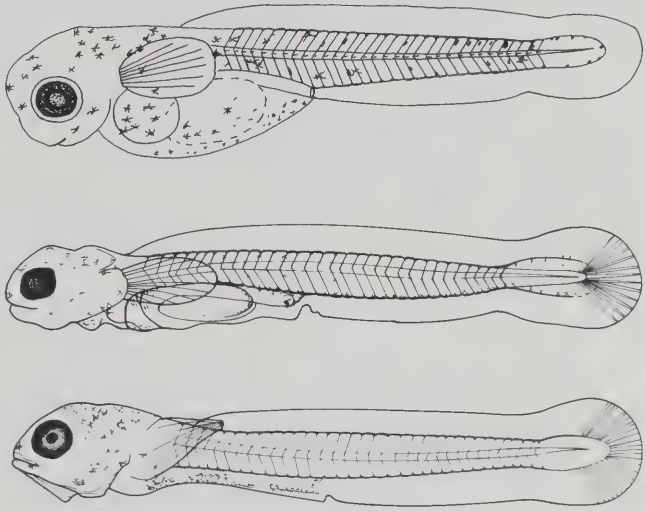

Fig. 7.—Top: *Etheostoma microperca* hatchling (3.5 mm total length). Middle: 3-day-old larva (4.0 mm total length). Bottom: 7-day-old juvenile (4.7 mm total length).

A series of 20 young *E. microperca* ranging from

7 to 13 mm was collected at the study site on 27 June 1976. At 7 mm all fins, fin rays, and branchiostegal rays were well developed; scales and the lateralis system were nonexistent; pigment was limited to discrete melanophores scattered over the head and body, and outlining fin rays and myomeres. At 8–9 mm 10 vague lateral blotches and 6–7 dorsal saddles were present, and more pigment was visible on the head, gill covers, and snout. At 10–11 mm the lateral blotches and dorsal saddles were well defined; pigment outlined the anal fin rays; scales were visible on the top and sides of the body; melanophores were beginning to outline the scales; the undersides, nape, and head were still devoid of scales; and the cephalic lateralis system was developed to its maximum. At 12–13 mm body squamation was complete, but no scales were present on the opercles; pigmentation on the head was like that of the adult, and the opercular spine was well developed.

Males and females grew at nearly the same decreasing rate (Fig. 8). The relationship between standard length (Y) and age in months (X) for males is $Y = 11.3 + 15.09 \log X$, with $r = 0.857$, and for females is $Y = 12.84 + 13.86 \log X$, with $r = 0.899$.

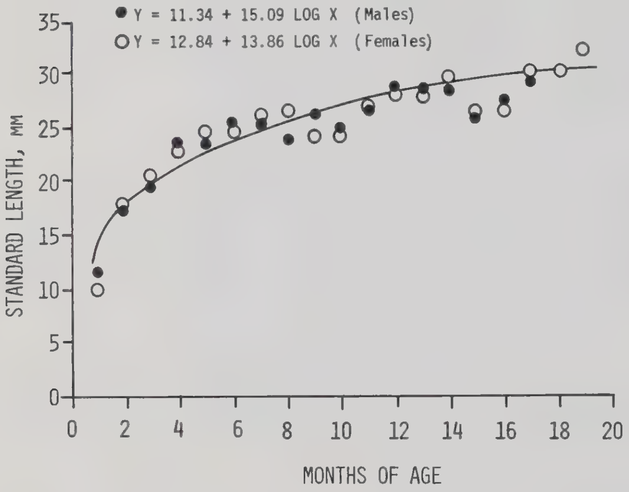

Fig. 8.—Size distribution by age of *Etheostoma microperca* collected in the Iroquois River between 5 August 1975 and 27 September 1976. Black dots represent sample means for males; circles represent sample means for females. Regression line is for both sexes. A total of 700 specimens is represented.

The largest specimen examined from the study area was a 32.4-mm female collected on 11 December 1975; the largest male was 31.5 mm collected on 27 September 1976. The largest specimen known is a 36.9-mm female from Spring Creek, Mayes County, Oklahoma. In general females reach a greater maximum size than do males, probably because females live longer.

At 1 year (12 months) males ($N = 11$) averaged 28.4 mm and females ($N = 24$) averaged 28.1 mm. *E. microperca* reached one-half of the first year's mean growth in about 6 or 7 weeks. *E. proeliare* required about 8 weeks to reach one-half of the first year's mean growth (Burr & Page 1978:11).

DEMOGRAPHY

Density

Quantitative samples of *E. microperca* were taken at the study area every month by repeatedly seining an area until no more individuals were present in some seine hauls. The number collected was transposed into the number per square meter (Table 3). The greatest density was 33.09 darters/m² collected on 14 October 1975.

The considerable variation in density (Table 3) seems to follow a seasonal trend and also emphasizes certain life history phenomena. From late summer through fall the species reached its greatest density at the study area. This is presumably due to a concentration of individuals by the extremely low water levels and the presence of both −1 and 1+ year classes. During winter months the density decreased; few individuals in the 1+ year class survived, and there was a rise in the water level due to fall rains and winter snows. In spring the density remained low. In late summer the numbers in the population began to build to the maximum attained in the fall.

Table 3.—Number of *Etheostoma microperca* per square meter in the Iroquois River by month of collection.

Collection Date	Number Collected	Number per Square Meter
14 October 1975	92	33.09
13 November 1975	70	11.78
11 December 1975	58	4.00
20 January 1976	26	2.33
12 February 1976	13	0.93
27 March 1976	13	0.84
27 April 1976	17	2.44
23 May 1976	12	0.83
27 June 1976	15	2.12
27 July 1976	29	3.81
30 August 1976	31	13.90
27 September 1976	40	26.85

E. microperca was the most common species of fish at the study area and it reached greater densities than those reported for other darters studied. The highest density found for *E. proeliare* was 5.5 individuals/m² (Burr & Page 1978:11). Schenck & Whiteside (1976:702) reported that the highest density found for *E. fonticola* at San Marcos River, Hays County, Texas, was 4.7 individuals/m².

Composition

Of the 700 *E. microperca* collected in the Iroquois River between 5 August 1975 and 27 September 1976, 82.0 percent were up to 1 year of age and 18.0 percent were between 1 and 2 years of age (Table 4).

There was no significant deviation from a 1 to 1 sex ratio in the first year (−1) age class but because of greater longevity females predominated [1.7 females to 1 male ($\chi^2 = 8.12$; $P < 0.005$)] in the 1+ year class.

Survival

Of the 314 males collected, 85.0 percent were up to 1 year of age and 15.0 percent were over 1 year of age. Of the 386 females collected 79.5 percent were up to 1 year of age and 20.5 percent were over 1 year of age. Assuming that each year class was collected in proportion to its relative number in the population, 17.6 percent of the first-year males and 25.7 percent of the first-year females survived to a second year. For males and females combined, the survival to a second year was 21.9 percent. These survival values and those of *E. proeliare* (Burr & Page 1978:11) are lower than those for other darters studied, and the short life span of the species of *Microperca* is a distinctive feature among percids. *E. smithi* is also a short-lived species: the oldest individual recorded was a 24-month old male (Page & Burr 1976:9).

The oldest *E. microperca* examined from the Iroquois River (assuming a May hatching) was a 20-month old female collected in December 1975. The oldest males examined were five 18-month old individuals collected in October 1975. Winn (1958*b*:182) reported seven 2-year-old specimens of *E. microperca* collected from his study sites in Michigan. His method for determining the age of specimens was not given.

Although *E. microperca* is short-lived, it can survive extreme environmental conditions. In a study of stream desiccation in Tenmile Creek, Lucas County, Ohio, Tramer (1977:475) found that *E. microperca* survived periods of drought by burrowing into the substrate. When rain refilled the dry pools in the creek, *E. microperca* reappeared.

Migration

E. microperca was common in the study area during most months of the study period and there was no indication of any mass movements up or down stream. Reference to breeding migrations observed in other populations was made under Spawning.

Territoriality

Territorial behavior, as discussed briefly under Reproductive Cycle of the Male, was observed in the field and laboratory. The aquaria used in this study could have been overcrowded, which, according to Winn (1958*a*:202), results in abnormal behavior and possibly inhibits full expression of territoriality. Petravicz (1936) did not observe territorial behavior and it was not observed in the related *E. proeliare* (Burr & Page 1978:11) and *E. fonticola* (Strawn 1956). According to Winn (1958*b*:168) *E. microperca* defended a small (ca. 25–30 cm) "stationary" territory which had three dimensions. The three dimensional territory of *E. microperca* included the vertical height of the plant as the third dimension. According to Winn territorial defense was not maintained at night.

TABLE 4.—Distribution of sexes and year classes in samples of *Etheostoma microperca* collected in the Iroquois River between 5 August 1975 and 27 September 1976.

Sex	Number by Year Class		Total
	−1	1+	
Males	267	47	314
Females	307	79	386
Total	574	126	700

DIET

Stomachs of 120 *E. microperca* contained mostly chironomid larvae and small crustaceans (Table 5). Gastropods, annelids, and insects other than chironomids made only small contributions to the diet. Compared to other darters studied, e.g., *Percina sciera* (Page & Smith 1970), *P. phoxocephala* (Page & Smith 1971), *P. nigrofasciata* (Mathur 1973), *Etheostoma squamiceps* (Page 1974), *E. kennicotti* (Page 1975), and *E. smithi* (Page & Burr 1976), the three species of the subgenus *Microperca* fed more on small crustaceans and less on insects other than chironomids (Burr & Page 1978:11; Schenck & Whiteside 1977*b*). Reasons for this were discussed by Burr & Page (1978: 11–12) and Schenck & Whiteside (1977*b*:490).

Isopods, cladocerans, copepods, and chironomids were major components of the diet of *E. microperca* of all sizes. Gastropods, plecopterans, and several kinds of dipterans were important to large (22–30 mm) *E. microperca*. In darters which attain a larger maximum size than do species of *Microperca*, small crustaceans are important to smaller individuals but decreasingly so with an increase in the size of the darter.

Chironomids and copepods were important diet items every month of the year (Table 6). Isopods and cladocerans were important diet items several months of the year. Fish eggs were consumed during spring months. Strawn (1956:17) and Schenck & Whiteside (1977*b*) reported that *E. fonticola* cannibalized newly hatched larvae and eggs. Petravicz (1936:81) indicated that supernumerary males of *E. microperca* may devour eggs fertilized by rival males.

Forbes (1880:26) and Forbes & Richardson (1920: 318) concluded that in Illinois small crustaceans made up 64 percent of the diet of *E. microperca*, *Chironomus* 34 percent, and ephemerids (Neuroptera) 2 percent. Forbes (1888: 516, 517, 524, 527, 529, 531) gave some indication of seasonal feeding habits with the groups mentioned above being eaten during May and June. Cahn (1927:56) reported that *E. microperca*

TABLE 5.—Stomach contents of *Etheostoma microperca* from the Iroquois River, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred				Mean Number of Food Organisms per Stomach			
	<16 mm (10)	16–21 mm (20)	22–27 mm (45)	>27 mm (45)	<16 mm (10)	16–21 mm (20)	22–27 mm (45)	>27 mm (45)
Gastropoda	......	5.0	13.3	4.0	......	0.10	0.22	0.04
Annelida								
Lumbricidae	......	......	......	8.0	......	......	......	0.24
Crustacea								
Cladocera	10.0	45.0	37.8	24.0	0.80	2.10	2.80	1.14
Ostracoda	......	......	......	4.0	......	......	......	0.04
Copepoda	90.0	100.0	73.3	60.0	27.20	14.35	10.22	8.96
Isopoda								
Asellidae								
Asellus	40.0	15.0	17.8	38.0	0.70	0.55	0.56	1.30
Insecta								
Plecoptera	......	10.0	6.7	4.0	......	0.10	0.07	0.04
Odonata	......	5.0	......	......	......	0.05	......	......
Collembola								
Entomobryidae	......	......	......	2.0	......	......	......	0.02
Diptera								
Chironomidae	60.0	75.0	73.3	68.0	3.30	3.25	4.91	5.98
Tabanidae	......	......	4.4	4.0	......	......	0.04	0.04
Ephydridae	......	......	......	6.0	......	......	......	0.10
Simulidae	......	......	2.2	......	......	......	0.38	......
Lepidoptera								
Pyralididae	......	......	......	2.0	......	......	......	0.02
Fish eggs	......	......	4.4	6.0	......	......	0.07	0.14
Empty	......	......	2.2	4.0	......	......	0.02	0.04

in southern Wisconsin (Waukesha County) ate insect larvae, nymphs, and entomostraca.

INTERACTIONS WITH OTHER ORGANISMS

Competition

Pflieger (1971:280–281) suggested that the complementary distribution of *E. microperca* and *E. proeliare* in Missouri was a result of competition. The two species have been collected together in a stream in Oklahoma in years past but recent collections have produced only specimens of *E. proeliare*. Similarly, *E. microperca* was known by an old collection from a creek in southwestern Arkansas. Numerous recent collections in the creek have again produced only specimens of *E. proeliare*. Because the habitat requirements of the two species are similar, their complementary distributions may be due at least in part to competition.

Other than *E. microperca* the only darter captured in the study area was *E. nigrum*. *E. nigrum* usually inhabited the central portion of the stream in sandy stretches and was never common. No evidence of competition involving *E. microperca* was found at the study area.

Predation

As potential predators of *E. microperca,* eight *Semotilus atromaculatus* (73–90 mm) and three *Lepomis cyanellus* (49–82 mm) were preserved and later examined. No fish remains were found in their stomachs.

Hankinson (1911:204) found remains of *E. microperca* in the stomachs of young "black bass" 2.5 inches long from Walnut Lake, Michigan. Cahn (1927:56) reported that the species was eaten by *Pomoxis annularis* and *Micropterus salmoides.* In an analysis of the feeding habits of two species of trouts from Birch Lake, Cass County, Michigan, Leonard & Leonard (1949:304) found that *E. microperca* was not eaten although it was present in the lake.

Parasitism

Of the 120 *E. microperca* in which stomach contents were examined, two each contained one spiny-headed worm *(Acanthocephalus* sp.). Parasitic nematodes were found in the stomachs from every month of the year except August and February. A total of 32 nematodes was found in the stomachs examined and up to 4 nematodes were found in an individual stomach. The only external infestation was a parasitic copepod *(Lernaea* sp.) found on a specimen collected in August.

In specimens examined from throughout the range of *E. microperca* external fluke infestations were found in four collections: OSM 16617 (Scioto River, Ohio); ROM 26803 (AuSable River, Ontario); UMMZ 136999 (Bad River, Michigan); UMMZ 139765 (Saline River, Michigan).

In a study of parasites in Lake Erie fishes Bangham & Hunter (1939:406) examined four specimens of *E. microperca* and found no infestations. The only published report of parasitism in this species is by

TABLE 6.—Stomach contents of *Etheostoma microperca* from the Iroquois River, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred												Mean Number of Food Organisms per Stomach											
	Jan. (10)	Feb. (10)	Mar. (10)	Apr. (10)	May (10)	June (10)	July (10)	Aug. (10)	Sept. (10)	Oct. (10)	Nov. (10)	Dec. (10)	Jan. (10)	Feb. (10)	Mar. (10)	Apr. (10)	May (10)	June (10)	July (10)	Aug. (10)	Sept. (10)	Oct. (10)	Nov. (10)	Dec. (10)
Gastropoda	......	......	......	10.0	10.0	10.0	......	......	......	......	20.0	40.0	......	......	......	0.10	0.10	0.20	......	......	......	......	0.30	0.70
Annelida																								
Lumbricidae	......	......	40.0	......	......	......	......	......	......	......	......	......	......	......	1.20	......	......	......	......	......	......	......	......	......
Crustacea																								
Cladocera	70.0	50.0	......	......	......	......	10.0	20.0	60.0	50.0	50.0	90.0	1.50	1.20	......	......	......	......	0.40	0.90	2.30	2.00	3.30	12.50
Ostracoda	......	10.0	10.0	......	......	......	......	......	......	......	......	......	......	0.10	0.10	......	......	......	......	......	......	......	......	......
Copepoda	90.0	100.0	40.0	40.0	50.0	50.0	60.0	80.0	100.0	100.0	80.0	90.0	3.40	51.40	1.30	0.90	1.20	1.30	4.60	27.90	18.30	16.60	4.30	13.70
Isopoda																								
Asellidae																								
Asellus	......	10.0	20.0	70.0	30.0	40.0	30.0	40.0	40.0	10.0	20.0	20.0	......	0.20	0.30	4.50	0.30	0.70	0.90	1.80	0.60	0.20	0.20	0.30
Insecta																								
Plecoptera	10.0	20.0	......	......	......	......	30.0	10.0	......	......	......	......	0.10	0.20	......	......	......	......	0.30	0.10	......	......	......	......
Odonata	......	......	......	......	......	......	10.0	......	......	......	......	......	......	......	......	......	......	......	0.10	......	......	......	......	......
Collembola																								
Entomobryidae	......	......	10.0	......	......	......	......	......	......	......	......	......	......	......	0.10	......	......	......	......	......	......	......	......	......
Diptera																								
Chironomidae	40.0	100.0	100.0	60.0	100.0	90.0	90.0	40.0	60.0	80.0	80.0	30.0	1.10	10.20	7.70	3.50	15.20	9.60	7.10	1.00	1.10	1.90	1.90	0.50
Tabanidae	......	10.0	30.0	......	......	......	......	......	......	......	......	......	......	0.10	0.30	......	......	......	......	......	......	......	......	......
Ephydridae	......	......	......	30.0	......	......	......	......	......	......	......	......	......	......	......	0.50	......	......	......	......	......	......	......	......
Simulidae	......	......	......	......	......	10.0	......	......	......	......	......	......	......	......	......	......	......	1.70	......	......	......	......	......	......
Lepidoptera																								
Pyralididae	......	......	......	......	......	......	......	......	......	......	......	10.0	......	......	......	......	......	......	......	......	......	......	......	0.10
Fish Eggs	......	......	......	30.0	......	20.0	......	......	......	......	......	......	......	......	......	0.40	......	0.60	......	......	......	......	......	......
Empty	......	......	......	20.0	......	......	......	......	......	......	......	10.0	......	......	......	0.20	......	......	......	......	......	......	......	0.10

Evermann & Clark (1920:450–457) who found that some individuals from Lake Maxinkuckee, Indiana, were infected with trematodes.

SUMMARY

The life-history information on *E. microperca* in Iroquois River is summarized in Table 7.

TABLE 7.—Summary of life-history information on the Iroquois River *Etheostoma microperca*.

Characteristic	Life-History Data
Principal habitat	Vegetated, sluggish water bodies with a bottom of sand or muck
Age at reaching sexual maturity	1 year
Age at first spawning	1 year
Size at reaching sexual maturity	All spring-collected individuals regardless of size were potential spawners
Sexual dimorphism	Adult males average smaller, have red-orange in their first dorsal, anal, and pelvic fins, develop cuplike appendages on their pelvic fins, and have longer heads, wider interorbital widths, longer postdorsal lengths, deeper caudal peduncles, and longer pelvic, pectoral, anal, and second dorsal fins
Breeding tubercles	Present on undersides of pelvic fins in males only (none found on anal fin in this population)
Description of genital papillae	Females have a swollen, conical papilla; males have a pointed, tubular papilla
Number of mature ova in preserved females	31–240
Description of egg	0.9 mm across, translucent (1–2 oil droplets) and prominently indented on one side
Spawning period	From April to June
Spawning habitat	Shallow, sluggish edges of stream in dense beds of filamentous algae
Egg deposition sites	Dead leaves, twigs, debris, filamentous algae
Number of eggs laid per spawning act	1–3
Spawning position	Both male and female in vertical position (rarely horizontal), male mounted on back of female
Egg guarding	None observed
Incubation period	264 ± 13 hours at 15.5°C, 181 ± 7 hours at 20°C, 144 ± 12 hours at 22°–23°C
Influence of sex on growth rate	Both sexes grew at approximately same rate
Density	Up to 33.09 darters/m^2 during fall along vegetated stream edges
Sex ratio among first year (–1) age class	1 male: 1 female
Sex ratio among 1+ year age class	1 male: 1.7 females
Longevity	20 months for females; 18 months for males
Maximum size	32.4 mm standard length for females; 31.5 mm standard length for males
Migrations	None observed
Territoriality	Males establish territories about plants at least during breeding season
Principal diet	Chironomid larvae and small crustaceans

LITERATURE CITED

BANGHAM, R. V., and G. W. HUNTER, III. 1939. Studies on fish parasites of Lake Erie. Distribution studies. Zoologica 24: 385–448.

BRAASCH, M. E., and P. W. SMITH. 1967. The life history of the slough darter, *Etheostoma gracile* (Pisces, Percidae). Illinois Natural History Survey Biological Notes 58. 12 p.

BRANSON, B. A., J. TRIPLETT, and R. HARTMANN. 1970. A partial biological survey of the Spring River drainage in Kansas, Oklahoma and Missouri. Part II. The fishes. Kansas Academy of Science Transactions 72(4):429–472.

BURR, B. M. 1978. Systematics of the percid fishes of the subgenus *Microperca*, genus *Etheostoma*. Alabama Museum of Natural History Bulletin 4. 53 p.

———, and M. S. ELLINGER. 1980. Distinctive egg morphology and its relationship to development in the percid fish *Etheostoma proeliare*. Copeia. In press.

———, and L. M. PAGE. 1978. The life history of the cypress darter, *Etheostoma proeliare*, in Max Creek, Illinois. Illinois Natural History Survey Biological Notes 106. 15 p.

CAHN, A. R. 1927. An ecological study of southern Wisconsin fishes; the brook silversides *(Labidesthes sicculus)* and the cisco *(Leucichthys artedi)* in their relations to the region. Illinois Biological Monographs 11:3–151.

EVERMANN, B. W., and H. W. CLARK. 1920. Lake Maxinkuckee, a physical and biological survey. Indiana Department of Conservation 1:1–600; 2:1–512.

FORBES, S. A. 1880. The food of fishes. Illinois State Laboratory of Natural History Bulletin 1(3):18–65.

———. 1888. On the food relations of fresh-water fishes: a summary and discussion. Illinois State Laboratory of Natural History Bulletin 2:475–538.

———, and R. E. RICHARDSON. 1920. The fishes of Illinois. 2nd ed. Illinois Natural History Survey. cxxxvi + 357 p.

HANKINSON, T. L. 1908. A biological survey of Walnut Lake, Michigan. Pages 157–288 *in* Michigan State Board Geological Survey Report for 1907.

———. 1911. Ecological notes on the fishes of Walnut Lake, Michigan. American Fisheries Society Transactions 40:195–206.

LEONARD, J. W., and F. A. LEONARD. 1949. An analysis of the feeding habits of rainbow trout and lake trout in Birch Lake, Cass County, Michigan. American Fisheries Society Transactions 76:301–314.

MATHUR, D. 1973. Some aspects of life history of the blackbanded darter, *Percina nigrofasciata* (Agassiz), in Halawakee Creek, Alabama. American Midland Naturalist 89(2):381–393.

PAGE, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps*, in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———. 1975. The life history of the stripetail darter, *Etheostoma kennicotti*, in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

———, and B. M. BURR. 1976. The life history of the slabrock darter, *Etheostoma smithi*, in Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 99. 12 p.

———, and P. W. Smith. 1970. The life history of the dusky darter, *Percina sciera,* in the Embarras River. Illinois Natural History Survey Biological Notes 69. 15 p.

———, and ———. 1971. The life history of the slenderhead darter, *Percina phoxocephala,* in the Embarras River, Illinois. Illinios Natural History Survey Biological Notes 74. 14 p.

Petravicz, J. J. 1936. The breeding habits of the least darter, *Microperca punctulata* Putnam. Copeia 1936(2):77–82.

Pflieger, W. L. 1971. A distributional study of Missouri fishes. University of Kansas Publications, Museum of Natural History 20(3):225–570.

———. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City. 343 p.

Schenck, J. R., and B. G. Whiteside. 1976. Distribution, habitat preference and population size estimate of *Etheostoma fonticola.* Copeia 1976(4):697–703.

———, and ———. 1977*a*. Reproduction, fecundity, sexual dimorphism and sex ratio of *Etheostoma fonticola* (Osteichthyes: Percidae). American Midland Naturalist 98(2):365–375.

———, and ———. 1977*b*. Food habits and feeding behavior of the fountain darter, *Etheostoma fonticola* (Osteichthyes: Percidae). Southwestern Naturalist 21(4):487–492.

Strawn, K. 1955. A method of breeding and raising three Texas darters. Part I. Aquarium Journal 26(12):408–412.

———. 1956. A method of breeding and raising three Texas darters. Part II. Aquarium Journal 27(1):11, 13–14, 17, 32.

Tramer, E. J. 1977. Catastrophic mortality of stream fishes trapped in shrinking pools. American Midland Naturalist 97(2):469–478.

Trautman, M. B. 1957. The fishes of Ohio. The Ohio State University Press, Columbus. 683 p.

Winn, H. E. 1958*a*. Observations on the reproductive habits of darters (Pisces-Percidae). American Midland Naturalist 59(1): 190–212.

———. 1958*b*. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecological Monographs 28(2):155–191.

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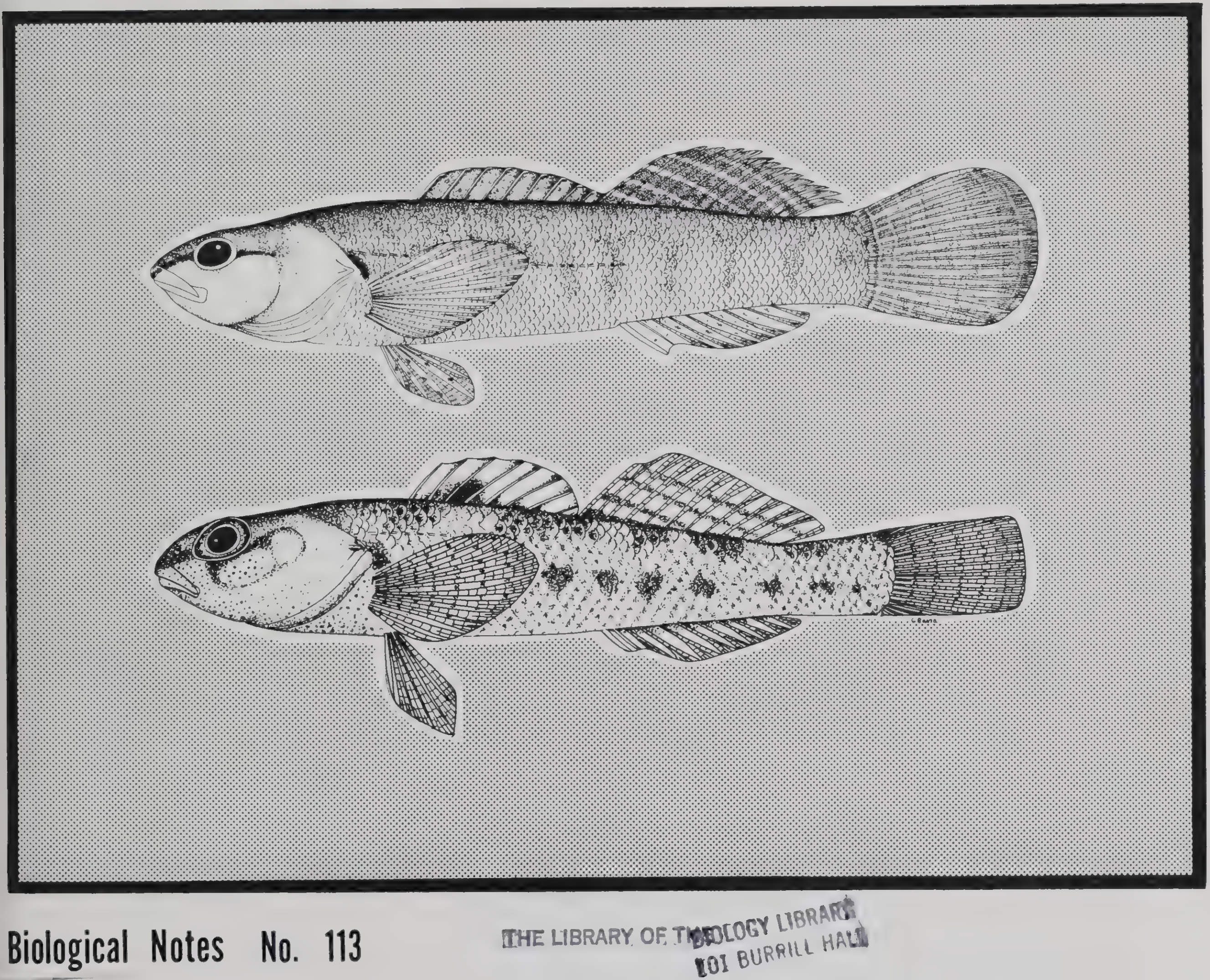
THE LIFE HISTORIES OF *Etheostoma olivaceum* AND *Etheostoma striatulum*, TWO SPECIES OF DARTERS IN CENTRAL TENNESSEE

Lawrence M. Page



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Urbana, Illinois August 1980

THE LIFE HISTORIES OF ETHEOSTOMA OLIVACEUM AND ETHEOSTOMA STRIATULUM, TWO SPECIES OF DARTERS IN CENTRAL TENNESSEE

Lawrence M. Page

The subgenus *Catonotus,* with 10 described species, is ecologically the best known group of darters. The inhabitation of slab-rock environments and the reproductive behavior, in which eggs are deposited on the undersides of stones and then guarded until hatching by the male, ecologically segregate *Catonotus* from all other darters. Other species of darters are found in slab-rock habitats but only certain species of *Catonotus* are restricted (as adults) to them. The habit of inverting and laying eggs on the undersides of stones is rare among darters and in addition to *Catonotus* is known only for the subgenus *Boleosoma* (known for three of the five species in the subgenus — Atz 1940, Winn 1958*a*, 1958*b*) and for *Etheostoma (Nothonotus) maculatum* (Raney & Lachner 1939).

Life-history studies on the dirty darter, *Etheostoma olivaceum,* and the striated darter, *Etheostoma striatulum,* bring to seven the number of species of the subgenus *Catonotus* for which a substantial amount of life-history information is available. The other species are *E. flabellare* (Lake 1936, Winn 1958*a,* 1958*b,* Karr 1964), *E. squamiceps* (Page 1974), *E. kennicotti* (Page 1975*a*), *E. smithi* (Page & Burr 1976), and *E. barbouri* (Flynn & Hoyt 1979).

E. olivaceum is limited in distribution (Fig. 1) to tributaries of the lower Caney Fork (Cumberland River system) and nearby small direct tributaries of the Cumberland River in central Tennessee (Braasch & Page 1979). Within this small area the species is abundant. *E. striatulum* occurs (Fig. 1) only in the upper Duck River system in Bedford, Marshall, and Maury counties in central Tennessee (Page & Braasch 1977) and is generally uncommon.

I am indebted to Brooks M. Burr, Richard L. Mayden, and Michael A. Morris, all of Southern Illinois University at Carbondale, for aid in collecting specimens; to Richard L. Mayden, Edward A. Lisowski, Liane B. Suloway, John K. Bouseman, and Donald W. Webb, all now or formerly of the Illinois Natural History Survey, for assisting with laboratory analyses; and to David F. Oetinger, Houghton College, for identification of internal parasites. Cover illustrations were done by Craig W. Ronto. Assistance in preparing other illustrations was provided by Illinois Natural History Survey Illustrator Lloyd LeMere and Survey Photographer Larry Farlow. The manuscript was typed by Bernice P. Sweeney and edited for publication by Shirley McClellan, Assistant Technical Editor at the Survey. Dr. Herbert Boschung, University of Alabama, served as guest reviewer. This study was supported by National Science Foundation grant DEB 76-15542.

STUDY AREAS AND METHODS

Brush Creek, at the town of Brush Creek in Smith County, Tennessee (Fig. 2), is a spring-fed, direct tributary of Caney Fork and supports a large population of *E. olivaceum.* Other fishes present, in approximate order of abundance are *Etheostoma atripinne, Pimephales notatus, Notropis* species (cf. *heterolepis*), *Cottus carolinae, N. telescopus, Fundulus catenatus, Campostoma anomalum, Hypentelium nigricans, Micropterus dolomieui, Phoxinus erythrogaster, N. ardens, Lepomis megalotis, L. cyanellus, L. macrochirus, E. flabellare,* and *Ictalurus melas.*

At the study area, Brush Creek averaged approximately 6 m wide and was rarely more than 50 cm deep. The substrate was mostly bedrock. Crevices in the bedrock were filled with rubble and gravel and formed small riffles. Slab rocks lined the margins of the stream and formed small shallow pools. Most trees and shrubs had been removed and grasses covered the banks. During the study period water temperatures ranged from 8.5° to 25°C.

Wartrace Creek, at the Route 82 bridge, 2 km east of Bell Buckle, Bedford County, Tennessee (Fig. 2), is one of the few known localities at which *E. striatulum* is moderately common. During the study period the stream averaged about 16 m in width. The depth averaged about 30 cm and reached a maximum of 1.5 m. Water temperatures varied from 2° to 25°C. The study area included one rubble riffle; the remainder consisted of a large pool above the riffle (Fig. 2). In the pool the substrate was mostly bedrock, but large expanses of gravel and, along the east bank, of silt were also present. Large flat stones were scattered over an area encompassing about one-fourth of the pool. Fishes encountered at the site, in approximate order of abundance, were *Pimephales notatus, Etheostoma squamiceps, Notropis ardens, E. striatulum, N. boops, Lepomis megalotis, Etheostoma* species (cf. *simoterum*), *E. atripinne, E. luteovinctum, L. macrochirus, Gambusia affinis, E. caeruleum, E. fla-*

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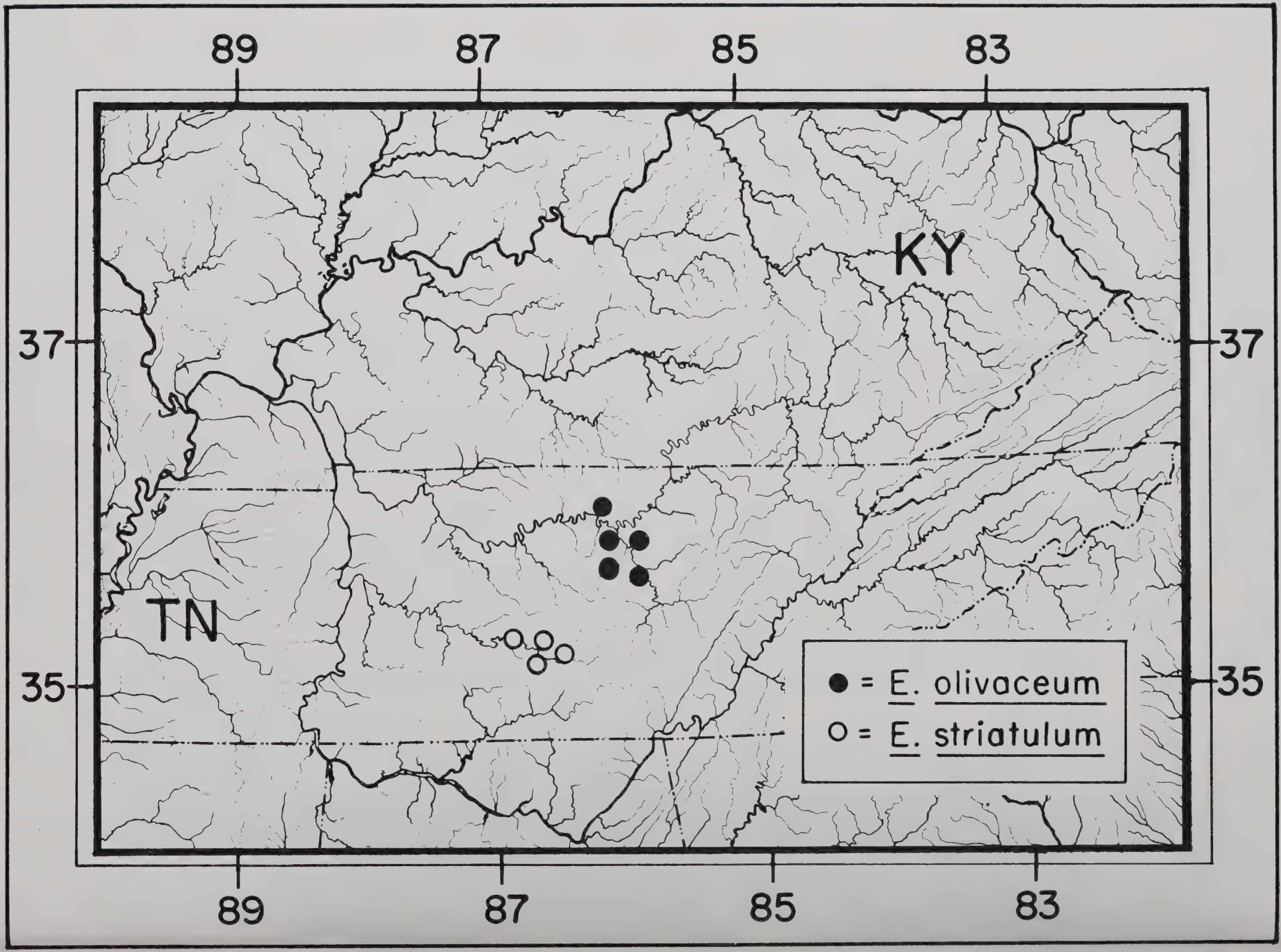
Cover Illustrations.—Drawings of *Etheostoma olivaceum* (Top) and *E. striatulum* (Bottom) by Craig W. Ronto.


89
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● = E. olivaceum
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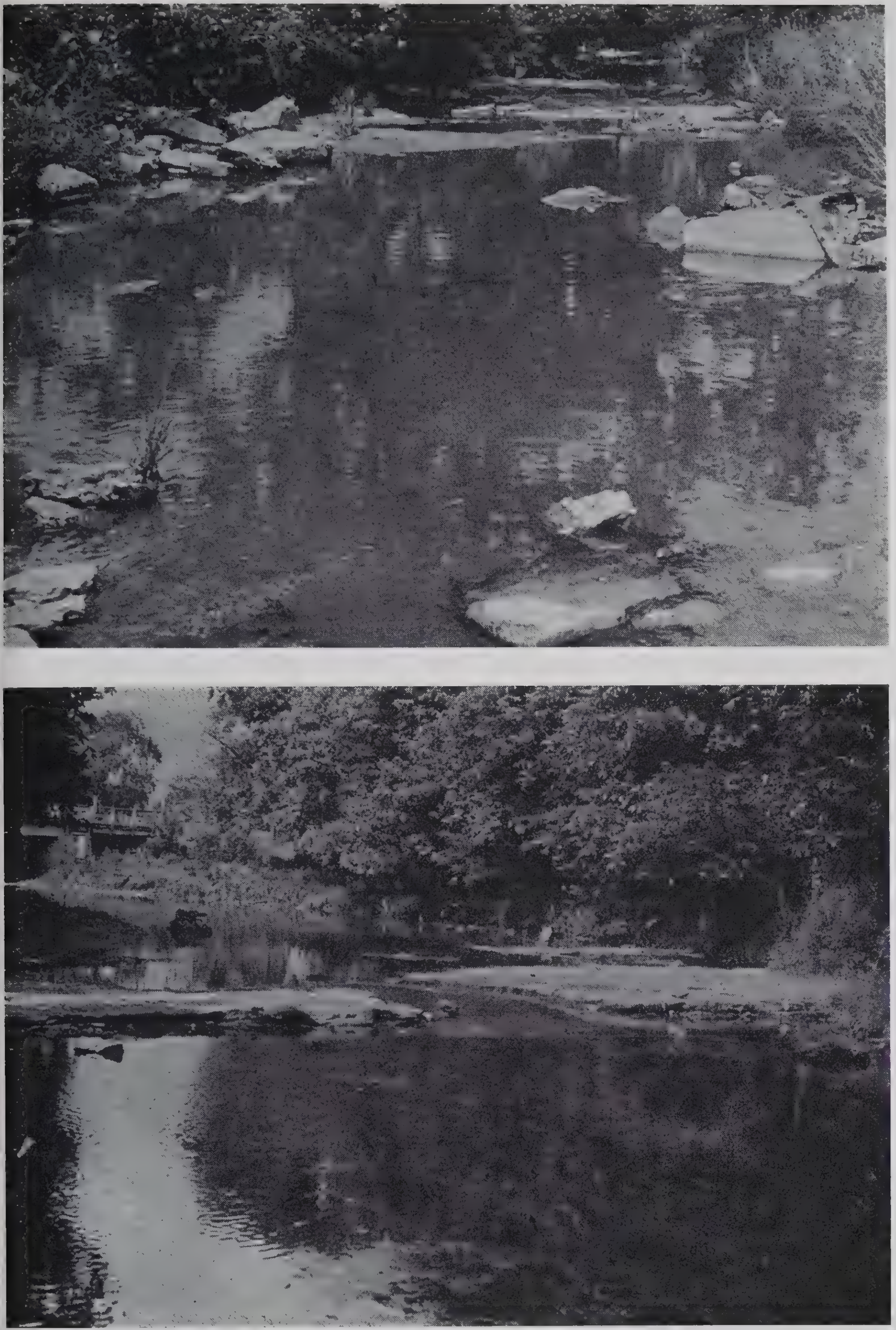

Fig. 2.—Top: Brush Creek study area, Smith County, Tennessee, 23 June 1977. Bottom: Wartrace Creek study area, Bedford County, Tennessee, 23 June 1977.

bellare, L. cyanellus, Fundulus notatus, Ambloplites rupestris, Cottus carolinae, Micropterus dolomieui, E. blennioides, F. catenatus, Semotilus atromaculatus, Moxostoma duquesnei, Ictalurus natalis, and *Hypentelium nigricans.*

Methods of study were the same as those used in the study of *E. squamiceps* (Page 1974:4–5) except that collections were made at about 2-month rather than 1-month intervals; collections were recorded as having been taken from riffles, bedrock pools, or slab pools; fin and caudal peduncle measurements were not taken; and functual regressions of weight on standard length were computed following Ricker (1973). Studies were begun at both sites on 12 December 1976 and terminated on 30 January 1979. Totals of 471 *E. olivaceum* and 191 *E. striatulum* were preserved and examined.

HABITATS

E. olivaceum inhabits only small (1st- and 2nd-order) streams and is not known from the mainstreams of either Caney Fork or the Cumberland River. In Brush Creek, young and adults were most common in slab-rock pools along the margins of the stream (Fig. 2); occasionally, they were found in riffles or bedrock pools.

E. striatulum inhabits small to moderate-sized streams; most individuals found have been in 2nd-order streams. In Wartrace Creek, most young and adults were captured by lifting large slab stones in water 0.1–1.0 m deep and kicking beneath the stone in the direction of a hand-held dipnet. No *E. striatulum* were captured in riffles and few were captured over open bedrock away from slab. A few small *E. striatulum* were captured by seining over gravel.

The affinities of *E. olivaceum* and of *E. striatulum* for slab pools were discussed by Page & Schemske (1978). Both species utilize slab stones as cover throughout the year and as nesting sites during the spawning season.

REPRODUCTION

Genital papillae of both nonbreeding and breeding *E. olivaceum* and *E. striatulum* are essentially identical to those illustrated for other species of *Catonotus* (Page 1974:6, 1975*a*:4; Page & Burr 1976:4).

Morphological descriptions, including those of breeding males, are given for *E. olivaceum* by Braasch & Page (1979) and for *E. striatulum* by Page & Braasch (1977). Females of both species undergo little (a few darken somewhat) or no color change prior to or during the breeding season and are essentially identical in color and pattern to nonbreeding females.

Reproductive Cycle of the Male

In March and April males of both species selected cavities under slab rocks and defended them as breeding territories. *E. olivaceum* males transferred to a 40-gallon aquarium in March 1977 became territorial (about 2 weeks after the transfer) and combative. Some territorial males, especially when encountering other males, were pigmented similar to *E. squamiceps* as described and figured by Page (1974:6); i.e., the sides of the body were white anteriorly and dark posteriorly with black vertical bars. Other territorial males remained mottled brown with no conspicuous pattern but with a bold black humeral spot and bold bright eye.

In *E. squamiceps,* only males reaching 40 mm or more by the end of the spawning season developed breeding colors and had enlarged testes; smaller males, including most 1-year-olds, apparently did not spawn (Page 1974). Similarly, *E. olivaceum* males less than about 43 mm failed to have breeding colors and enlarged testes and probably did not spawn. Observations in Brush Creek indicated that large males held a proportion of nests greater than their proportion in the male population and, as in other species of *Catonotus,* the largest males presumably did most of the spawning (Page 1974: 7, 1975*a*:5; Page & Burr 1976:5). Although in *E. squamiceps* there was no indication that 1-year-old males spawned, many of the *E. olivaceum* males found guarding nests were large 1-year-olds.

All of the April-collected males of *E. striatulum,* including the smallest (37 mm), had developed breeding colors and enlarged testes and were potential spawners. All were 1 year old.

Reproductive Cycle of the Female

As in other darters, ova development in *E. olivaceum* and in *E. striatulum* progressed most rapidly in the largest females. Small white ova appeared in both species as early as October, yellow ova as early as February, and orange ova in March.

In *E. olivaceum,* the relationship between the mean of the weight of the ovaries divided by the adjusted body weight (Y) and the month (X), with June = 1 and April = 11, was log Y = 0.458 + 0.151 X, with r = 0.981 (Fig. 3). The proportionally largest ovaries (equalling 28.8 percent of the adjusted body weight) were found in a 40-mm female collected on 16 April 1978. In *E. striatulum,* the relationship was log Y = 0.352 + 0.103 X, with r = 0.812 (Fig. 4). Although the ovaries of *E. striatulum* females failed to average heavier in March and April than in January and February (Fig. 4) they did contain maturing ova. The low numbers of mature ova in some of the females (Table 1) correspond to the low weights in March and April. The largest

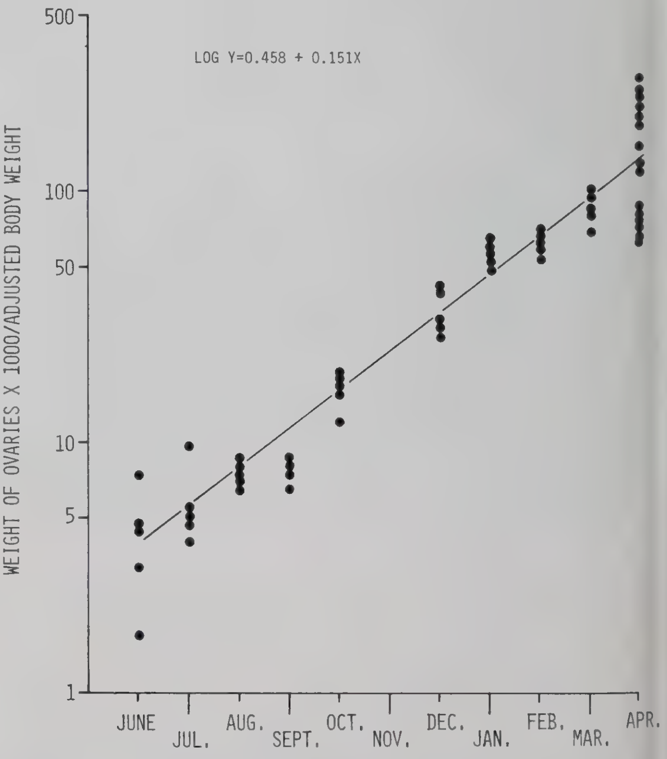

Fig. 3. — Monthly variations in ovarian weight relative to adjusted body weight of *Etheostoma olivaceum.*

ovaries (26.8 percent) found in *E. striatulum* were in a 1-year-old, 37-mm female collected on 14 April 1978.

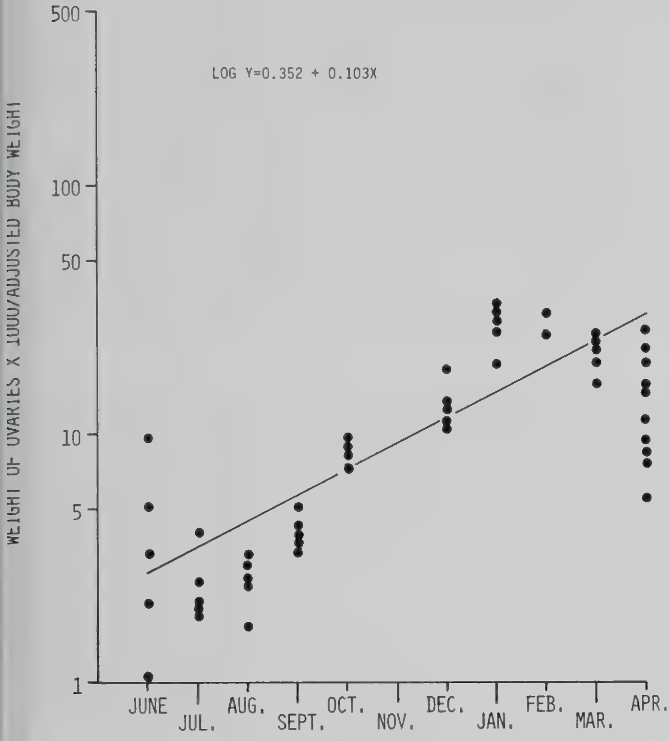

Fig. 4.—Monthly variations in ovarian weight relative to adjusted body weight of *Etheostoma striatulum*.

All April-collected females, including an *E. olivaceum* only 36 mm and an *E. striatulum* only 31 mm in length, contained mature ova and were potential spawners. In 9 ripe *E. olivaceum* the number of mature ova ranged from 60 to 112, and in 10 ripe *E. striatulum* ranged from 19 to 108 (Table 1). For these females there was no significant correlation between the number of mature ova and the standard length, nor between the number of mature ova and the adjusted body weight; for both relationships correlation values were less than 0.42 for both species. The highest correlation ($r = 0.417$) was the relationship between the number of ova and standard length of *E. striatulum*. One of the reasons suggested for a lack of correlation between the size of the female and number of ova in *E. proeliare* (Burr & Page 1978:6–7) was that all females examined were 1 year old and about the same size at spawning; this is also true of the *E. olivaceum* and *E. striatulum* females (Table 1). In species of *Catonotus* for which significant correlations were found between the size of the female and the number of ova, there was greater variation in the size of the females examined (Page 1974:8, 1975*a*:5; Page & Burr 1976:5).

In ripe females of both species, mature ova averaged about 1.8 mm in diameter, were translucent, had one or more large yellow oil droplets, and were indented on one side (Fig. 5). The indentation in the egg, previously described only for *E. proeliare*, *E. fonticola*, and *E. microperca* (Burr & Page 1978, 1979), is apparently a more widespread phenomenon among darters than indicated in those descriptions and in Burr (1978). Why it was not observed in other studies involving mature eggs of darters is unknown, although the indentation is visible only on fully mature eggs and it may appear only a short time before spawning.

Spawning

Nests of *E. olivaceum* eggs were found on the undersides of stones, a tin can and a piece of tile in Brush

Table 1.—Relationship between size and ovary weight of *Etheostoma olivaceum* and *E. striatulum* females and the number of mature ova produced. All females were 12 months old.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Ovary Weight in Grams	Number of Mature (Orange or Translucent) Ova
E. olivaceum			
37	0.72	0.09	60
40	0.87	0.25	73
41	1.06	0.20	74
42	0.99	0.18	90
42	1.03	0.25	75
44	1.10	0.17	98
44	1.27	0.32	112
44	1.30	0.33	69
45	1.31	0.16	72
E. striatulum			
31	0.39	0.06	19
33	0.47	0.04	31
35	0.62	0.04	45
35	0.64	0.10	46
37	0.56	0.05	59
37	0.60	0.16	61
38	0.73	0.06	108
39	0.71	0.16	45
41	0.85	0.10	30
43	1.16	0.23	92

[a] Adjusted body weight is the specimen's weight after the removal of the ovaries, stomach, intestine, and liver.

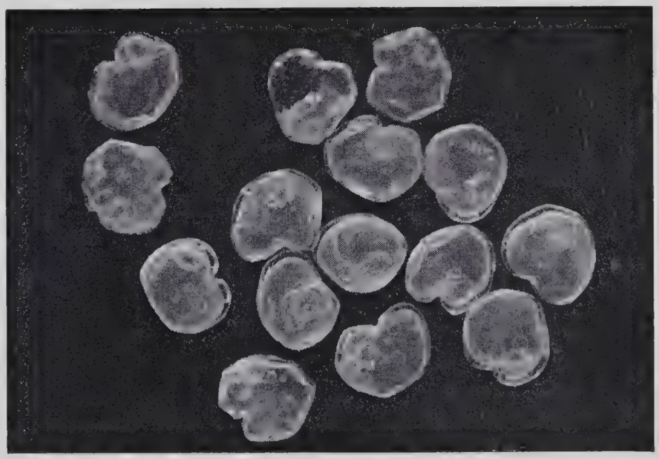

Fig. 5.—Fully mature eggs removed from an April-collected *Etheostoma olivaceum*.

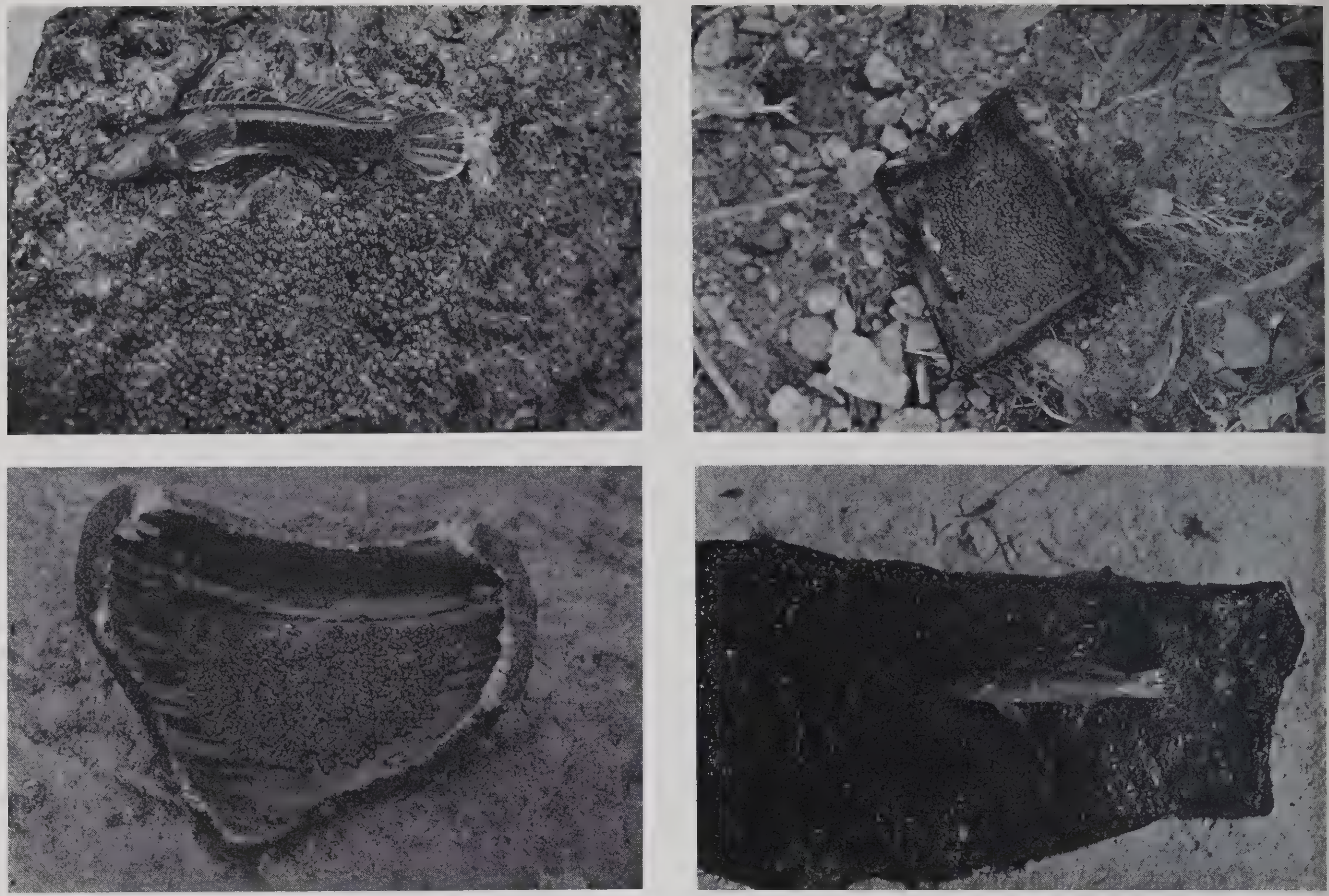

Fig. 6.—Nests of *Etheostoma olivaceum* removed from Brush Creek on 21 April 1977 and of *E. striatulum* removed from Wartrace Creek on 20 April 1977. Top left: *E. olivaceum* male and his nest of eggs on a stone. Top right: *E. olivaceum* eggs on a flattened and partly disintegrated metal can. Bottom left: *E. olivaceum* eggs on a piece of tile. Bottom right: *E. striatulum* male and his nest of eggs on a stone. All nests were on the undersides of the objects shown when submerged.

Creek on 21 April 1977 (water temperature = 17°C) and on 16 April 1978 (19°C). Several spawning pairs were interrupted as stones were lifted in Brush Creek on 16 April 1978. No nests were found on 3 March 1977 (9° C) or on 18 June 1977. The spawning period probably extends in most years from late March into May.

Counts and estimates of the numbers of eggs in 19 nests of *E. olivaceum* in Brush Creek were 107, 140, 200, 250, 250, 275, 300, 350, 400, 420, 450, 460, 475, 581, 643, 651, 725, 1050, and 1500 ($\bar{X} = 486$). Eggs in nests averaged 2 mm in diameter and were round and translucent.

Other species of *Catonotus* (*E. squamiceps, E. kennicotti, E. smithi*) spawned in aquaria when transferred from streams as ripe individuals (Page 1974:8, Page 1975*a*, 1975*b*; Page & Burr 1976:6). *E. olivaceum* also was transferred to aquaria but generally remained too wary to spawn and only one spawning act was witnessed (on 18 April 1978 at 27°C). The behavior observed during that one spawning act appeared to be identical to that of *E. squamiceps,* the closest relative of *E. olivaceum.* The female only briefly inverted to deposit eggs; in species of *Catonotus* other than *E. squamiceps* and *E. olivaceum* the female remains inverted for the duration of egg-laying, which may last for hours (Page 1975*b*).

Nests of *E. striatulum* eggs were found on the undersides of stones (Fig. 6) in Wartrace Creek on 20 April 1977 (22°C) and on 14 April 1978 (16°C) in water 10–45 cm deep. Counts and estimates of eggs in 11 nests were 25, 25, 47, 98, 130, 180, 190, 210, 225, 250, and 327 ($\bar{X} = 155$). Eggs averaged 2 mm in diameter and were round and translucent. Because of the small samples of *E. striatulum* collected, no attempt was made to transport live individuals to spawning tanks. The behavior of the closely related *E. smithi* was described by Page & Burr (1976:6).

The undersides of trash items were used as nesting sites by *E. olivaceum* in Brush Creek although most nests were on stones (Fig. 6). As in nests of other species of *Catonotus,* eggs of *E. olivaceum* and *E. striatulum* were packed closely in a concentrated area but were not laid on top of one another (an exception to this general rule was noted in *E. neopterum* — Page & Mayden 1979). In one instance, two nests of *E. olivaceum* were found on one stone when lifted from the stream. The proximal margins of the nests were 15 cm apart and presumably when the stone was partially embedded in the stream bed the two guarding males were hidden from one another. In Wartrace Creek on 20 April 1977 and on 14 April 1978, nests of *E. squamiceps* were about three times as common as those of *E. striatulum*. One stone, measuring about 20 x 30 cm, was used simultaneously by *E. striatulum* and *E. squamiceps*. The margins of the two nests were about 8 cm apart; the centers of the nests were about 15 cm apart. Three nests of *Pimephales notatus* were also found on these two dates on the undersides of slab stones similar to those used by *E. striatulum* and *E. squamiceps*.

Males of *E. olivaceum* and of *E. striatulum* remain under their nest stones after spawning and guard the eggs until hatching.

DEVELOPMENT AND GROWTH

Nests of *E. olivaceum* eggs were transferred from Brush Creek to a laboratory aquarium and kept at 22° ± 3°C until hatching. *E. olivaceum* hatchlings 0–22 hours-old (N = 8) averaged 6.6 mm in total length and, with well-developed jaws and pectoral fins (Fig. 7), were morphologically similar to other *Catonotus* hatchlings. Hatchlings were nearly translucent with few melanophores. Fin rays were present only in the incipient pectoral and caudal fins.

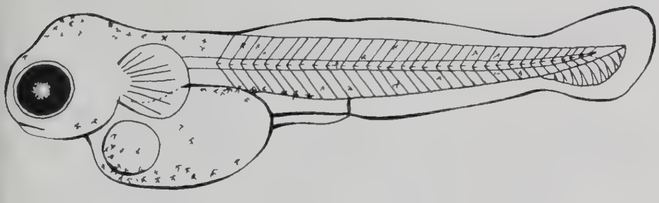

Fig. 7.—*Etheostoma olivaceum* hatchling (7 mm total length).

On 18 June 1977 49 young *E. olivaceum* ranging from 15 to 28 mm were collected in the study area. Individuals shorter than 20 mm had prominent round spots along the midside and distinct dorsal blotches. On those longer than 20 mm the color pattern was mottled and essentially identical to that of the adult. On the smallest specimen (15 mm) the lateral line was present on only one scale, squamation was complete except on the nape and belly, and the infraorbital canal was nearly but not fully formed. On individuals 20 mm and longer, the lateral line extended to at least the origin of the first dorsal fin, squamation was complete, and the infraorbital canal was fully formed.

For *E. olivaceum* males the relationship between standard length (Y) and age in months (X) was Y = 7.1 + 35.67 log X, with $r = 0.877$, and for females was Y = 11.1 + 29.92 log X, with $r = 0.829$ (Fig. 8). At 12 months males averaged 48.5 mm and were significantly ($t = 4.06$, df = 66) longer than females (averaging 41.8 mm). One half of the first year's mean growth was reached in about 10 weeks; this is somewhat less time than that estimated (12–16 weeks) for other species of *Catonotus* (Page 1974:12, 1975*a*:9; Page & Burr 1976:9). The largest specimen examined from Brush Creek was a 64.8-mm male collected on 30 January 1979; the largest specimen of the species recorded is 67 mm (Braasch & Page 1979).

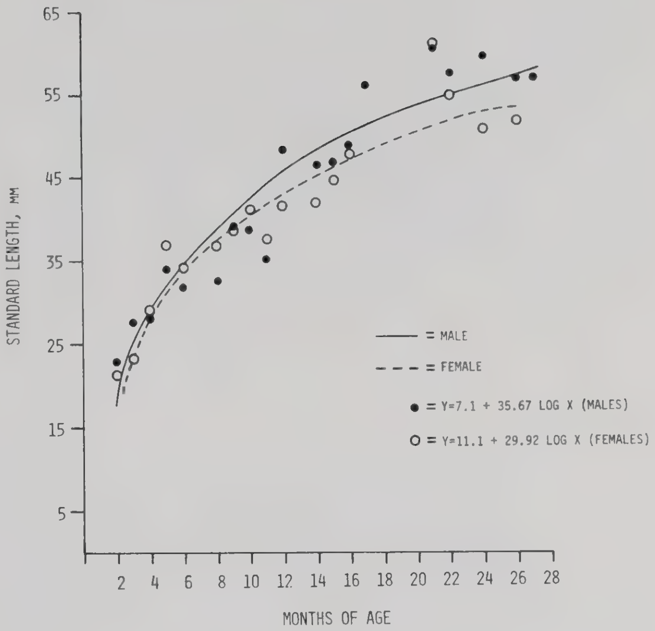

Fig. 8.—Size distribution by age of *Etheostoma olivaceum* collected in Brush Creek between 12 December 1976 and 30 January 1979. Black dots represent sample means for males; circles represent sample means for females. A total of 471 specimens is represented.

For *E. striatulum* males the relationship between standard length (Y) and age in months (X) was Y = 11.2 + 26.32 log X, with $r = 0.881$, and for females was Y = 14.6 + 20.00 log X, with $r = 0.798$ (Fig. 9). At 12 months, males, averaging 43.8 mm, were significantly ($t = 4.40$, df = 20) longer than females, which averaged 37.0 mm. As in *E. olivaceum,* one half of the first year's mean growth was reached in about 10 weeks. The largest specimen examined from Wartrace Creek, and the largest specimen of *E. striatulum* known, is a 48.7-mm male collected on 20 April 1977.

For *E. olivaceum* (N = 100) the functional regression (Ricker 1973) of weight (W) on standard length (L) was log W = −4.142 + 2.591 log L, with $r = 0.838$; and for *E. striatulum* (N = 82) was log W = −4.375 + 2.695 log L, with $r = 0.852$.

DEMOGRAPHY

Density

Density samples of *E. olivaceum* were taken in Brush Creek and of *E. striatulum* in Wartrace Creek by repeatedly seining an area until no more individuals were collected. On 10 August 1977 the density of *E.*

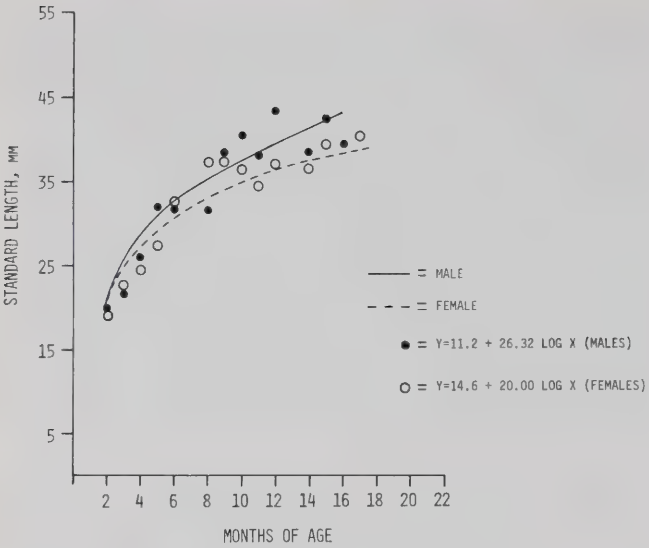

Fig. 9.—Size distribution by age of *Etheostoma striatulum* collected in Wartrace Creek between 12 December 1976 and 30 January 1979. Symbols as in Fig. 8. A total of 191 specimens is represented.

olivaceum in slab pools, the preferred habitat, was found to be 0.03 individuals per m^2. On 30 January 1979 densities of *E. olivaceum* per m^2 were: in slab pools, 0.07; in riffles, 0.02; in bedrock pools, 0.01. On 30 January 1979, 0.01 *E. striatulum* per m^2 were found in the slab-rock portion (about one-fourth) of the large pool constituting the study area.

Composition

Of the 471 *E. olivaceum* collected in Brush Creek between 12 December 1976 and 30 January 1979, 90.0 percent were up to 1 year of age, 9.1 percent were over 1 and up to 2 years, and 0.9 percent were over 2 years (Table 2). Sex ratios were skewed in favor of females in the first-year class (1.7 females to 1 male; $\chi^2 = 27.51$, $P < 0.005$) and in the total sample (1.6 females to 1 male; $\chi^2 = 28.08$, $P < 0.005$). Females have predominated in other *Catonotus* populations studied, with ratios varying from 1.2:1 to 1.7:1, as discussed by Page (1974:13, 1975*a*:10), Page & Burr (1976:9), and Flynn & Hoyt (1979:134).

Of the 191 *E. striatulum* collected in Wartrace Creek between 12 December 1976 and 30 January 1979, 94.8 percent were up to 1 year of age and 5.2 percent were between 1 and 2 years of age (Table 2). Unlike in other species of *Catonotus,* the sex ratio did not deviate significantly from 1:1.

Survival

Of the 178 *E. olivaceum* males collected, 88.8 percent were up to 1 year of age, 9.6 percent were over 1 and up to 2 years, and 1.7 percent were over 2 years. Of the 293 females, 90.8 percent were up to 1 year of age, 8.9 percent were over 1 and up to 2 years, and 0.3 percent were over 2 years. Only 10.8 percent of the first-year males and 9.8 percent of the first-year females (10.1 percent of the combined sexes) survived to a second year. Only 17.6 percent of the second-year males and 3.8 percent of the second-year females (9.3 percent with sexes combined) survived to a third year. The oldest *E. olivaceum* from Brush Creek (assuming an April hatching) was a 27-month-old male collected in July 1978.

Of the 87 *E. striatulum* males collected, 95.4 percent were up to 1 year of age and only 4.6 percent were over 1 year. Of the 104 females collected 94.2 percent were up to 1 year of age and 5.8 percent were over 1 year. Assuming each age class was collected in proportion to its relative number in the Wartrace Creek population, only 4.8 percent of the first-year males and 6.1 percent of the first-year females survived to a second year. The survival to a second year for males and females combined was 5.5 percent. Survival values for *E. striatulum* are lower than those found for other species of *Catonotus* (Page 1974:13–14, 1975*a*:10–11; Page & Burr 1976:9) but are similar to those for *E. proeliare* (Burr & Page 1978:10–11). Both *E. striatulum* and *E. proeliare* are essentially annual fishes, with few individuals living beyond 1 year of age. The oldest *E. striatulum* from Wartrace Creek examined (assuming an April hatching) was a 17-month-old female collected in September 1978.

Migration

E. olivaceum and *E. striatulum* were found with relative ease at the study areas during every visit and no indication of any seasonal movements up or downstream or from one habitat to another was apparent.

Table 2.—Distribution of sexes and year classes in samples of *Etheostoma olivaceum* and *E. striatulum* collected between 12 December 1976 and 30 January 1979.

Sex	Number by Year Class			Total
	+	1+	2+	
		E. striatulum		
Male	83	4	. . .	87
Female	98	6	. . .	104
Total	*181*	*10*	. . .	*191*
		E. olivaceum		
Male	158	17	3	178
Female	266	26	1	293
Total	*424*	*43*	*4*	*471*

DIET

Stomach contents of 72 *E. olivaceum* and 51 *E. striatulum* were analyzed and tabulated by size class of darter (Tables 3 and 4) and by month of collection (Tables 5 and 6). For both species the diet consisted, as it has in almost all darters studied, mainly of aquatic insects and small crustaceans. Chironomid larvae were consumed in large numbers by all size classes (Tables 3 and 4). Small darters also fed heavily on microcrustaceans and large darters also fed on large insects (stone-

ERRATUM

The first paragraph on page 10 of The life histories of *Etheostoma olivaceum* and *Etheostoma striatulum*, two species of darters in central Tennessee should read as follows:

olivaceum in slab pools, the preferred habitat, was found to be 4.04 individuals per m^2. On 30 January 1979 densities of *E. olivaceum* per m^2 were: in slab pools, 8.07; in riffles, 1.79; in bedrock pools, 1.47. On 30 January 1979, 1.34 *E. striatulum* per m^2 were found in the slab-rock portion (about one-fourth) of the large pool constituting the study area.

TABLE 3.—Stomach contents of *Etheostoma olivaceum* from Brush Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred					Mean Number of Food Organisms per Stomach				
	<21 mm (6)	21–30 mm (16)	31–40 mm (17)	41–50 mm (17)	>50 mm (16)	<21 mm (6)	21–30 mm (16)	31–40 mm (17)	41–50 mm (17)	>50 mm (16)
Oligochaeta	...	12.5	...	...	6.3	...	0.13	...	...	0.19
Gastropoda	...	...	5.9	...	...	...	...	0.06	...	...
Arachnida										
Acarina	...	...	11.8	5.9	6.3	...	...	0.18	0.71	0.13
Crustacea										
Cladocera	16.7	43.8	17.6	...	...	0.33	1.06	0.35	...	...
Ostracoda	16.7	6.3	23.5	...	...	0.17	0.06	0.29	...	...
Copepoda	66.7	50.0	29.4	17.6	...	7.33	8.19	5.12	0.24	...
Isopoda	...	6.3	...	11.8	6.3	...	0.06	...	0.12	0.06
Amphipoda	...	...	5.9	...	12.5	...	...	0.06	...	0.13
Insecta										
Plecoptera	...	...	5.9	5.9	6.3	...	...	0.12	0.06	0.06
Ephemeroptera	16.7	25.0	23.5	47.1	31.3	0.17	0.31	0.24	0.59	0.75
Hemiptera										
Gerridae	...	...	...	5.9	...	...	...	...	0.06	...
Trichoptera	...	...	5.9	11.8	12.5	...	...	0.06	0.12	0.13
Coleoptera										
Dytiscidae	...	...	11.8	...	...	...	...	0.12	...	...
Elmidae	...	...	...	5.9	...	...	...	...	0.06	...
Others	...	...	11.8	...	...	...	...	0.23	...	...
Diptera										
Tipulidae	...	...	...	11.8	...	...	...	...	0.12	...
Simuliidae	...	...	5.9	11.8	6.3	...	...	0.06	0.29	0.19
Chironomidae	100.0	87.5	100.0	100.0	62.5	11.17	5.31	13.94	16.12	7.88
Others	...	12.5	5.9	5.9	...	...	0.19	0.06	0.12	...

flies and caddisflies). Mayflies were ingested rather frequently by all sizes of *E. olivaceum* and by *E. striatulum* greater than 21 mm.

For both species food consumption was heaviest in March, just before the spawning period (Tables 5 and 6).

PREDATION AND PARASITISM

Few potential predators were captured at either study site. At Brush Creek, four *Cottus carolinae* (66–105 mm) and one *Lepomis macrochirus* (87 mm) were preserved and later examined; none contained fish remains in its stomach or gut. At Wartrace Creek two *Cottus carolinae* (48–90 mm), one *Micropterus dolomieui* (90 mm), and one *Lepomis megalotis* (63 mm) were examined. The only ingested fish was a 40-mm *Campostoma anomalum* in the stomach of the 90-mm *C. carolinae*.

In the 72 stomachs of *E. olivaceum* examined, 8

TABLE 4.—Stomach contents of *Etheostoma striatulum* from Wartrace Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred				Mean Number of Food Organisms per Stomach			
	<21 mm (6)	21–30 mm (16)	31–40 mm (16)	>40 mm (13)	<21 mm (6)	21–30 mm (16)	31–40 mm (16)	>40 mm (13)
Crustacea								
Cladocera	66.7	31.3	12.5	...	1.17	0.44	0.13	...
Ostracoda	50.0	6.3	18.8	...	0.50	0.06	0.19	...
Copepoda	100.0	68.8	31.3	53.8	9.33	3.06	0.69	1.38
Insecta								
Plecoptera	...	12.5	6.3	15.4	...	0.13	0.06	0.16
Ephemeroptera	...	12.5	6.3	7.7	...	0.19	0.06	0.08
Trichoptera	...	...	6.3	...	...	...	0.06	...
Diptera								
Simuliidae	...	6.3	...	...	...	0.06	...	...
Chironomidae	66.7	87.5	100.0	69.2	1.17	7.63	10.38	14.61
Others	...	6.3	6.3	7.7	...	0.06	0.06	0.08

Table 5.—Stomach contents of *Etheostoma olivaceum* from Brush Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred								Mean Number of Food Organisms per Stomach							
	Feb. (7)	Mar. (11)	Apr. (10)	June (6)	July (6)	Aug. (6)	Oct. (6)	Dec. (21)	Feb. (7)	Mar. (11)	Apr. (10)	June (6)	July (6)	Aug. (6)	Oct. (6)	Dec. (21)
Oligochaeta	14.3	...	...	...	33.3	...	...	...	0.43	...	...	...	0.33	...	...	...
Gastropoda	...	...	10.0	...	...	...	...	...	...	...	0.10	...	...	...	...	...
Arachnida																
Acarina	...	...	40.0	...	...	...	...	...	...	...	1.70	...	...	...	...	...
Crustacea																
Cladocera	...	9.1	...	...	16.7	66.7	50.0	4.8	...	0.18	...	...	0.33	1.00	1.67	0.09
Ostracoda	...	9.1	...	16.7	16.7	16.7	...	9.5	...	0.09	...	0.17	0.17	0.17	...	0.14
Copepoda	...	27.3	...	33.3	66.7	83.3	66.7	19.0	...	4.18	...	1.83	16.00	11.67	10.83	2.04
Isopoda	...	9.1	...	...	16.7	...	...	9.5	...	0.09	...	...	0.17	...	...	0.10
Amphipoda	14.3	9.1	...	...	...	...	...	4.8	0.14	0.09	...	...	...	...	...	0.05
Insecta																
Plecoptera	42.9	...	...	...	...	...	...	...	0.57	...	...	...	...	...	...	...
Ephemeroptera	14.3	9.1	60.0	50.0	33.3	16.7	50.0	23.8	0.14	0.09	0.90	0.83	1.00	0.17	0.67	0.24
Hemiptera																
Gerridae	...	...	...	...	...	...	...	4.8	...	...	...	...	...	...	...	0.05
Trichoptera	...	18.2	10.0	...	...	...	...	9.5	...	0.18	0.10	...	...	...	...	0.10
Coleoptera																
Dytiscidae	...	...	20.0	...	...	...	...	...	...	...	0.20	...	...	...	...	...
Elmidae	...	...	...	...	...	...	...	4.8	...	...	...	...	...	...	...	0.05
Others	...	...	...	...	...	33.3	...	...	...	...	...	...	...	0.67	...	...
Diptera																
Tipulidae	...	...	...	...	...	...	...	9.5	...	...	...	...	...	...	...	0.10
Simuliidae	...	9.1	30.0	...	...	...	...	...	...	0.09	0.80	...	...	...	...	...
Chironomidae	100.0	100.0	80.0	83.8	66.7	66.7	100.0	90.5	12.0	29.82	10.20	1.00	1.00	1.17	6.50	7.29
Others	...	...	...	...	...	...	33.3	4.8	...	...	...	...	...	...	0.50	0.05

Table 6.—Stomach contents of *Etheostoma striatulum* from Wartrace Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organisms Occurred								Mean Number of Food Organisms per Stomach							
	Feb. (4)	Mar. (10)	Apr. (8)	June (6)	July (6)	Aug. (6)	Oct. (4)	Dec. (7)	Feb. (4)	Mar. (10)	Apr. (8)	June (6)	July (6)	Aug. (6)	Oct. (4)	Dec. (7)
Crustacea																
Cladocera	...	...	12.5	50.0	50.0	16.7	50.0	14.3	...	...	0.13	0.83	0.83	0.17	0.50	0.29
Ostracoda	...	10.0	12.5	33.3	16.7	...	...	28.6	...	0.10	0.13	0.33	0.17	...	...	0.29
Copepoda	25.0	70.0	37.5	100.0	100.0	33.3	25.0	42.9	0.25	1.40	1.13	6.67	10.00	0.67	0.25	0.57
Insecta																
Plecoptera	25.0	...	...	...	50.0	16.7	...	...	0.25	...	...	...	0.50	0.17	...	...
Ephemeroptera	...	20.0	...	...	16.7	...	...	14.3	...	0.20	...	...	0.33	...	...	0.14
Trichoptera	...	...	12.5	...	...	...	...	...	...	...	0.13	...	...	...	...	...
Diptera																
Simuliidae	...	...	...	...	...	...	25.0	...	...	...	...	...	...	...	0.25	...
Chironomidae	100.0	100.0	75.0	66.7	66.7	83.3	100.0	85.7	3.50	36.90	1.88	4.16	0.83	2.17	1.75	5.25
Others	...	...	...	...	16.7	33.3	...	...	...	...	...	...	0.17	0.33	...	...

contained a total of 22 spinyheaded worms (*Acanthocephalus*). No parasitic worms were found in *E. striatulum.*

The most common external parasites, on 19 of 471 *E. olivaceum* and 17 of 191 *E. striatulum,* were fluke metacercariae. The metacercariae were found in almost all months in which collections were made. Parasitic copepods (*Lernaea*) were found on three *E. striatulum* collected in August.

CONSERVATION OF *E. STRIATULUM*

E. striatulum is known from fewer than a dozen localities, all in the Duck River system of Bedford, Marshall and Maury counties, Tennessee. It is moderately common in Wartrace Creek at the Route 82 bridge in Bedford County and at one or two other sites but is uncommon elsewhere. Although *E. striatulum* may never have been abundant, most present populations are small. The small populations and the low survival rate found at Wartrace Creek indicate that perpetuation of the species is uncertain.

Perpetuation of *E. striatulum* depends on the preservation of the natural characteristics of streams within its range. No historical data on fish populations are available for comparison; however, much of the land in Bedford and Marshall counties is farmland and streams in these counties probably are more heavily silted now than in the past and are reduced in size due to the loss of water being diverted to agricultural use. The streams in which *E. striatulum* occurs, especially Wartrace Creek with its relatively large population of *E. striatulum,* should be spared from further modifications.

Table 7.—Summary of life history information on *Etheostoma olivaceum* in Brush Creek and *E. striatulum* in Wartrace Creek.

Characteristic	*E. olivaceum*	*E. striatulum*
Principal habitat	Slab pools	Slab pools
Age at reaching sexual maturity	1 year	1 year
Age at first spawning	1 year	1 year
Size at reaching sexual maturity	Females about 35 mm; males about 40 mm	Females about 30 mm; males about 35 mm
Sexual dimorphism	Males are larger and, in spring, are much darker	Males are larger and more colorful
Number of mature ova counted	60–112	19–108
Description of egg in nest	2.0 mm in diameter, translucent and round	2.0 mm in diameter, translucent and round
Spawning period	From late March into May	From late March into May
Spawning habitat	Slab pools	Slab pools
Spawning position	Both male and female briefly inverted (one observation)	Unknown
Egg deposition site	Undersides of stones	Undersides of stones
Number of eggs counted in nests	107–1500	25–327
Egg guarding	Only by the male	Only by the male
Influence of sex on growth rate	At 1 year males are significantly larger than females	At 1 year males are significantly larger than females
Sex ratio among young	1.7 females: 1 male	1.2 females: 1 male
Longevity	27 months	17 months
Maximum size	65 mm	49 mm
Migrations	None	None
Territoriality	Extreme in breeding males	Extreme in breeding males
Principal diet	Aquatic insect immatures and crustaceans	Aquatic insect immatures and crustaceans

LITERATURE CITED

Atz, J. W. 1940. Reproductive behavior in the eastern johnny darter, *Boleosoma nigrum olmstedi* (Storer). Copeia 1940 (2):100–106.

Braasch, M. E., and L. M. Page. 1979. Systematic studies of darters of the subgenus *Catonotus* (Percidae), with the description of a new species from Caney Fork, Tennessee. University of Kansas Museum of Natural History Occasional Papers 78. 10 p.

Burr, B. M. 1978. Systematics of the percid fishes of the subgenus *Microperca,* genus *Etheostoma.* Bulletin of the Alabama Museum of Natural History 4. 53 p.

———, and L. M. Page. 1978. The life history of the cypress darter, *Etheostoma proeliare,* in Max Creek, Illinois. Illinois Natural History Survey Biological Notes 106. 15 p.

———, and ———. 1979. The life history of the least darter, *Etheostoma microperca,* in the Iroquois River, Illinois. Illinois Natural History Survey Biological Notes 112. 16 p.

Flynn, R. B., and R. D. Hoyt. 1979. The life history of the teardrop darter, *Etheostoma barbouri* Kuehne and Small. American Midland Naturalist 101(1):127–141.

Karr, J. R. 1964. Age, growth, fecundity and food habits of fantail darters in Boone County, Iowa. Iowa Academy of Science Proceedings 71:274–280.

Lake, C. T. 1936. The life history of the fan-tailed darter *Catonotus flabellaris flabellaris* (Rafinesque). American Midland Naturalist 17(5):816–830.

Page, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps,* in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

———. 1975*a.* The life history of the stripetail darter, *Etheostoma kennicotti,* in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

———. 1975*b.* Relations among the darters of the subgenus *Catonotus* of *Etheostoma.* Copeia 1975(4):782–784.

———, and M. E. Braasch. 1977. Systematic studies of darters of the subgenus *Catonotus* (Percidae), with the description of a new species from the Duck River system. University of Kansas Museum of Natural History Occasional Papers 63. 18 p.

———, and B. M. Burr, 1976. The life history of the slabrock darter, *Etheostoma smithi,* in Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 99. 12 p.

———, and R. L. Mayden. 1979. Nesting site of the lollypop darter, *Etheostoma neopterum.* Kentucky Academy of Sciences Transactions 40(1–2):56–57.

———, and D. W. Schemske. 1978. The effect of interspecific competition on the distribution and size of darters of the subgenus *Catonotus* (Percidae:*Etheostoma*). Copeia 1978 (3):406–412.

Raney, E. C., and E. A. Lachner. 1939. Observations on the life history of the spotted darter, *Poecilichthys maculatus* (Kirtland). Copeia 1939(3):157–165.

Ricker, W. E. 1973. Linear regressions in fishery research. Canadian Fisheries Research Board Journal 30(3):409–434.

Winn, H. E. 1958*a.* Observations on the reproductive habits of darters (Pisces-Percidae). American Midland Naturalist 59(1):190–212.

———. 1958*b.* Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecological Monographs 28(2):155–191.

DENTIFICATION and DESCRIPTIONS OF HE ULTIMATE INSTAR LARVAE OF *ydraecia immanis* (Hop Vine Borer) nd *H. micacea* (Potato Stem Borer) (Lepidoptera: Noctuidae)

George L. Godfrey

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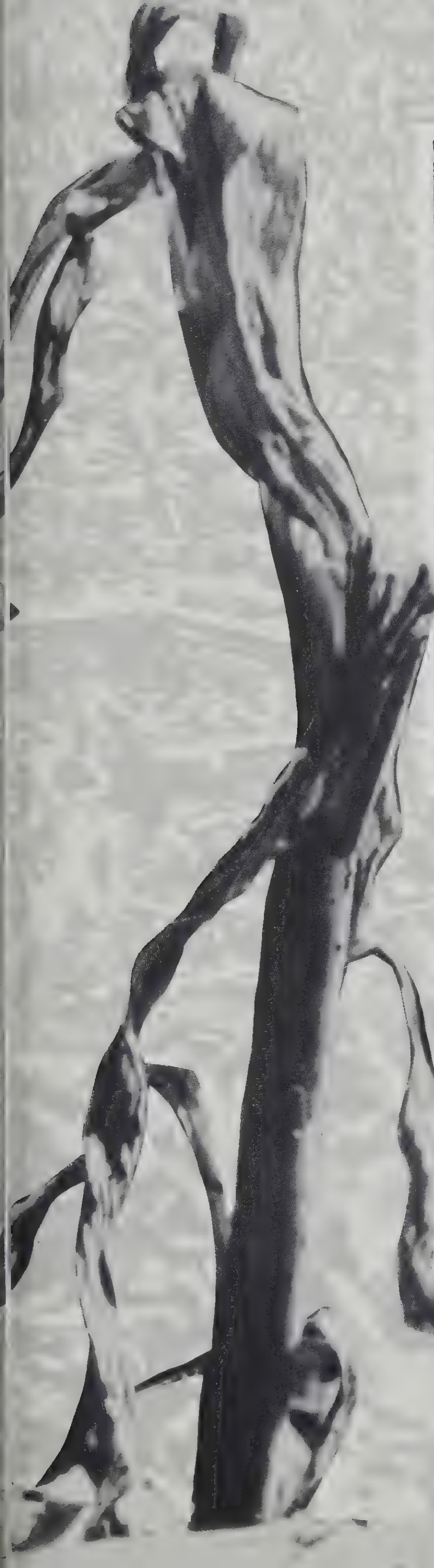


Biological Notes No. 114

Illinois Natural History Survey
Champaign, Illinois February 1981

State of Illinois
Illinois Institute of Natural Resources
Natural History Survey Division

Identification and Descriptions of the Ultimate Instar Larvae of Hydraecia immanis (Hop Vine Borer) and H. micacea (Potato Stem Borer) (Lepidoptera: Noctuidae)

George L. Godfrey

The distribution of and economic damage caused by two species of stalk and root boring noctuid caterpillars, *Hydraecia immanis* Guenée (hop vine borer) (Fig. 1) and *H. micacea* (Esper) (potato stem borer), are being monitored by entomologists in several regions of the USA, especially Illinois, Iowa, Minnesota, New York, and Wisconsin, because of recent problems associated with these species in field and sweet corn (*Zea mays* L.). (*Hydroecia* has been used by many North American authors, but Nye [1975] pointed out that it is an unjustifiable emendation of *Hydraecia.*) In the corn growing areas of these states one or both species have caused rather extensive, although localized, feeding damage.

H. immanis is native to North America, and the moth occurs from "Quebec to Virginia, west to the west coast" (Forbes 1954). Its caterpillar has been reported from corn before, but its greatest previously associated economic damage has been with hop (*Humulus lupulus* L.) (Hawley 1918). Two other recorded hosts are *Silphium* sp. (Compositae) and *Lupinus microcarpus* Sims (Leguminosae) (Tietz 1972). Reared adults of *Hydraecia immanis* from Cicero, Illinois, are in the collection of the Illinois Natural History Survey, with host-plant labels corroborating Tietz's published record of *Silphium,* but I do not know of any sources that authenticate the association with *Lupinus microcarpus,* a western plant species that occurs on Vancouver Island and coastal Puget Sound, extends southward to Baja California, and also is found in Chile (Hitchcock et al. 1961).

Hydraecia micacea is a polyphagous Palaearctic species that apparently was introduced to the New World in Nova Scotia and New Brunswick around the turn of the century (Gibson 1909). Gibson (1909) recorded the localities of the first corn associations for the larva of *H. micacea* in North America as Mahone, Nova Scotia, 1906, and Tramore, Ontario, 1907. The distribution of *H. micacea* in the USA until recently was confined to the extreme northeastern states, perhaps due in part to the barrier afforded by the Hudson and St. Lawrence river valleys, the Great Lakes, and the several mountain ranges in that area. But Muka (1976 and personal communication) reported infestations of *H. micacea* in field corn in 1975 in New York (St. Lawrence, Franklin, Clinton, and Essex counties). He and Professor John G. Franclemont (personal communication) subsequently have seen *H. micacea* on corn in several other New York counties (Monroe, Orleans, Niagara, Jefferson, Lewis, Oneida, Herkimer, Wayne, Cayuga, and Oswego) and *H. immanis* in Onondaga County.

Farther west, larvae of *Hydraecia* have been seen in field corn during June in increasing numbers since 1976 in a region that centers on northern Illinois, southwestern Wisconsin, southeastern Minnesota, and northeastern Iowa (Fig. 2). The area of most severe infestation to date has been in Fillmore County, Minnesota, necessitating the replanting of 2,000 acres of corn in 1979 (S. F. Tutt personal communication). There is some confusion regarding the identity of *Hydraecia* found in field corn in the Midwest as a result of tentative determinations applied to larvae collected in the field. The most widely circulated name has been *H. micacea* (Fig. 3), but adults reared from larvae collected in Illinois during 1978 were identified by me and later confirmed by Franclemont as *H. immanis* (Fig. 4). A reared adult from Fillmore County, Minnesota, in 1979 proved to be *H. immanis* also.

The ultimate larval instar of each species has been described several times. Bethune (1873) gave the earliest account of the larva of *H. immanis* although at the time he acknowledged not knowing its identity. The first published association between the larva and moth of *H. immanis* is Comstock's (1883). Some of the earliest larval descriptions of *H. micacea* by North American entomologists, in addition to Gibson's (1909), are Brittain's (1915 and 1918). Presently, no taxonomic literature exists that can be reliably used to identify and separate the mature larvae of *H. immanis* and *H. micacea.* Hence, the following comparative larval descriptions and illustrations are provided to promote positive determinations. Other species of North American *Hydraecia* (dependent in degree on the generic definition of this taxon) may feed on corn, but *H. immanis* and *H. micacea* are the only ones positively associated to date. I believe that the following information will aid in monitoring distributional changes and in the development of pest management

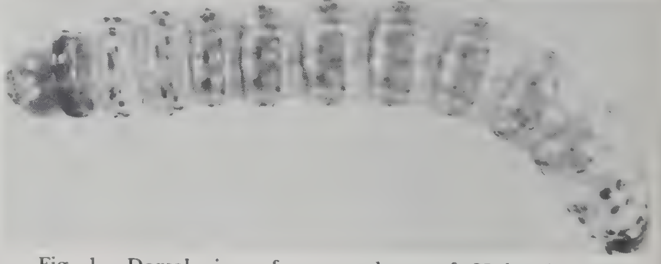


Fig. 1.—Dorsal view of mature larva of *Hydraecia immanis* (about 2.0X life size).

This paper is published by authority of the State of Illinois and is a contribution from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. George L. Godfrey is an Associate Taxonomist at the Survey.

Cover Illustration.—Larva of *Hydraecia immanis* and damaged cornfield in Clayton County, Iowa (Photographs by Jerry DeWitt, Extension Coordinator, Integrated Pest Management, Iowa State University, Ames, Iowa).

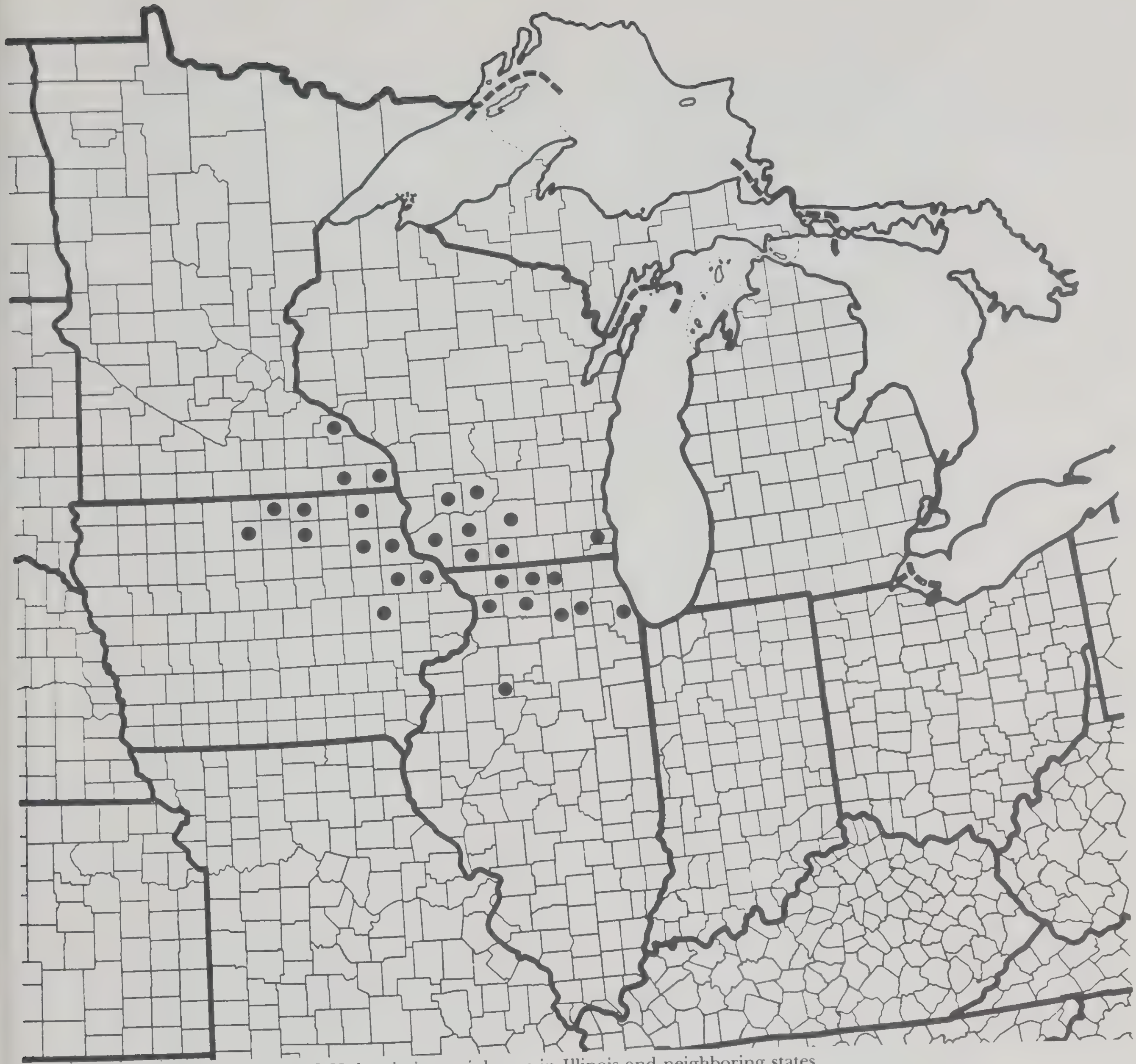


Fig. 2.—Distributional records of *Hydraecia immanis* larvae in Illinois and neighboring states.

programs for *H. immanis* and *H. micacea*. The morphological terminology and abbreviations used in this paper have been used previously (Godfrey 1972).

DESCRIPTIONS

Hydraecia immanis Guenée

General. Head smooth, width 3.00–3.58 mm. Body uniformly cylindrical, length 29–35 mm; appears smooth, but numerous, minute granules visible at 100X, especially along anterior edge of cervical shield. All setae simple, body setae arising from conspicuous pinacula. Prolegs present on Ab3–6 and 10; subequally developed. Crochets uniordinal and in mesoseries.

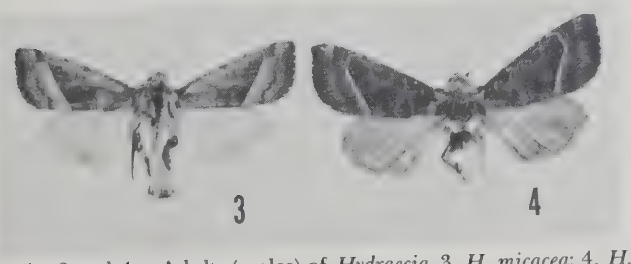


Fig. 3 and 4.—Adults (males) of *Hydraecia*. 3, *H. micacea*; 4, *H. immanis* (0.92X life size).

Head. Postgenal sutures parallel to each other; length of epicranial suture 1.56 times distance from apex of frons to Fa's (Fig. 9); distance F1–F1, 0.50–0.72 mm; AFa cephalad and AF2 caudad of frons apex; A1–3 form obtuse angle at A2; distances P1–P1 and P2–P2 subequally spaced; P1's distinctly closer to epicranial suture than to L; L cephalad of juncture of adfrontal ecdysial lines; margin of antennal socket convexly produced; distance Oc1–Oc2, 0.10–0.14 mm; Oc2–Oc3, 0.06–0.08 mm; Oc3–Oc4, 0.05–0.07 mm.

Mouthparts. Mediobasal area of oral surface of labrum has scattered, thin, short spines. Hypopharyngeal complex (Fig. 10): spinneret elongate, tubular, narrowing distad, with acute apex greatly surpassing tip of Lp2; length about 2.9 times that of Lps1. Length of Lps1, 2.1 times that of stipular seta, 13.0 times that of Lp1, 6.0 times that of Lps2, 4.3 times that of Lp2. Distal region without spines except for very short, fine ones laterad; proximomedial region lacks spines; proximolateral region bears numerous thin spines that become stouter and longer proximad. Mandible (Fig. 11): two outer setae present, closely spaced; inner tooth absent; inner ridges reduced, terminating before cutting edge; first outer tooth reduced, triangular, inconspicuous; outer teeth 2–5 triangular; sixth outer tooth reduced, rounded.

Thorax. Segment T1: SD1 and SD2 setal insertions contiguous with or slightly separated from lateral edge of cervical shield (Fig. 5 and 14); interspace D1–D1 about 0.68 times the distance XD1–XD1; D2–SD2 about 2.3 times the distance SD2–XD2; seta SD1 minute, inconspicuous; L2 insertion minute, seta absent; spiracle broadly elliptical, length about 2.0 times width, major axis passing caudad of SD and SV setal insertions. Segments T2 and T3 (Fig. 14): distance D1–D2 about 0.8 times distance D2–SD2; SD1 hairlike; coxal bases distinctly separated. Tarsal setae 1–3 slightly thickened, 4 merely setose; base of tarsal claw reduced, weakly convex.

Abdomen. Segment Ab1 has 2 SV setae. Segments Ab2–6 have 3 SV setae each, 1 each on Ab7 and Ab8. Chaetotaxy of Ab6, Ab7 as in Fig. 15. Segment Ab9: SD1 semihairlike, much thinner and shorter than D1 and D2. Segment Ab10: posterior margin of anal shield entire; anal shield convex with but slight transverse depression before posterior margin; subanal setae unmodified, subequal to lateral setae of anal proleg.

Coloration (Fig. 1). Head orange to reddish brown (head of earlier instars may be yellow), essentially immaculate, some specimens show very faint reticulation; clypeus ranges from solid orange to dark brown; ocelli and ocellar area dark brown to black; mandibles reddish brown to black. Body ground color sordid white, underlaid by transverse, violet bands on segments T2 through Ab8; bands interrupted by thin, white continuous middorsal and subdorsal lines (Fig. 6) (violet bands fade before prepupal stage); conspicuous dark brown to black pinacula present dorsally, subdorsally and laterally; setae white; spiracles brown with black peritremes; cervical shield (Fig. 5) glossy, pale brownish orange, with distinct black anterolateral margin; anal shield dark brown to black; cervical and anal shields interrupted by thin, whitish middorsal line.

Material examined. ILLINOIS: De Kalb, 23 June 1965, corn, H. B. Petty, 1 larva; Boone County, 10 June 1976, *Zea mays* L., C. Bremer, 2 larvae; Carroll County, 14 June 1978, *Zea mays* L., 4 larvae; Boone County, June 1978, *Zea mays* L., C. Bremer, 1 larva; Stephenson County, June 1979, corn, 6 larvae. IOWA: Clayton County, 12 June 1978, corn, 1 larva; Winneshiek County, 15 June 1979, corn, 2 larvae. MINNESOTA: Houston County, 22 June 1976, P. Sreenivasam, 7 larvae; Fillmore County, 22 June 1979, corn, J. Lofgren, 11 larvae; Fillmore County, June 1979, corn, S. F. Tutt, 8 larvae. NEW YORK: Onondaga County, Pompey, 7 July 1978, corn, A. A. Muka/M. E. Philipps, 3 larvae. WISCONSIN: Racine, 24 June 1926, International Harvester Company, 1 larva; northern Iowa County, 26 June 1979, corn, P. Pellitteri, 2 larvae; Richland County, near Excelsior (Dobbs' Farm), 19 June 1979, field corn, J. M. Scriber, (12 larvae), 25 June 1979 (31 larvae), 3 July 1979 (24 larvae).

Hydraecia micacea (Esper)

General. Head smooth, width 2.75–3.16 mm. Body uniformly cylindrical, length 25–31 mm; appears smooth, but numerous, minute granules visible at 100X, most distinctive along anterior edge of cervical shield. All setae simple, body setae arising from conspicuous pinacula. Prolegs present on Ab3–6, 10; subequally developed. Crochets uniordinal and in mesoseries.

Head. Postgenal sutures parallel to each other; length of epicranial suture 1.51 times distance from apex of frons to Fa's (Fig. 12); distance F1–F1, 0.44–0.52 mm; AFa cephalad and AF2 caudad of apex of frons; A1–3 form obtuse angle at A2; distances P1–P1 and P2–P2 subequally spaced; P1's about 0.33 times closer to epicranial suture than to L; L cephalad of juncture of adfrontal ecdysial lines; margin of antennal socket distinctly flanged outward; distance Oc1–Oc2, 0.08–0.10 mm; Oc2–Oc3, 0.05–0.08 mm; Oc3–Oc4, 0.04–0.06 mm.

Mouthparts. Mediobasal area of oral surface of labrum has thin, short spines. Hypopharyngeal complex (Fig. 13): spinneret elongate, tubular, bluntly tipped, with apex distinctly surpassing tip of Lp2; length about 2.3 times greater than length of Lps1. Length of Lps1, 1.7 times that of stipular seta, 6.7 times those of Lp1 and Lps2, 5.0 times that of Lp2. Distal region bare except for few, scattered, short, stout spines located laterad; proximomedial region lacks spines; proximolateral region bears short, stout spines, length increasing proximad. Mandible (Fig. 11): two outer setae present, closely spaced; inner ridges reduced, terminating before cutting edge; first outer tooth reduced, rounded.

Thorax. Segment T1: SD1 and SD2 setal insertions very narrowly separated from edge of cervical shield (Fig. 7 and 16); interspace D1–D1 about 0.66 times the distance XD1–XD1; D2–SD2 about 1.9 times the distance SD2–XD2; seta SD1 minute, inconspicuous; L2 insertion minute, seta absent; spiracle narrowly elliptical, sides of peritreme nearly parallel to each other, spiracle length about 2.4 times width, major axis of spiracle caudad of SD and SV setal insertions. Segments T2 and T3 (Fig. 16): distance D1–D2 about 0.8 times distance D2–SD2; SD1 hairlike; coxal bases distinctly separated. Tarsal setae

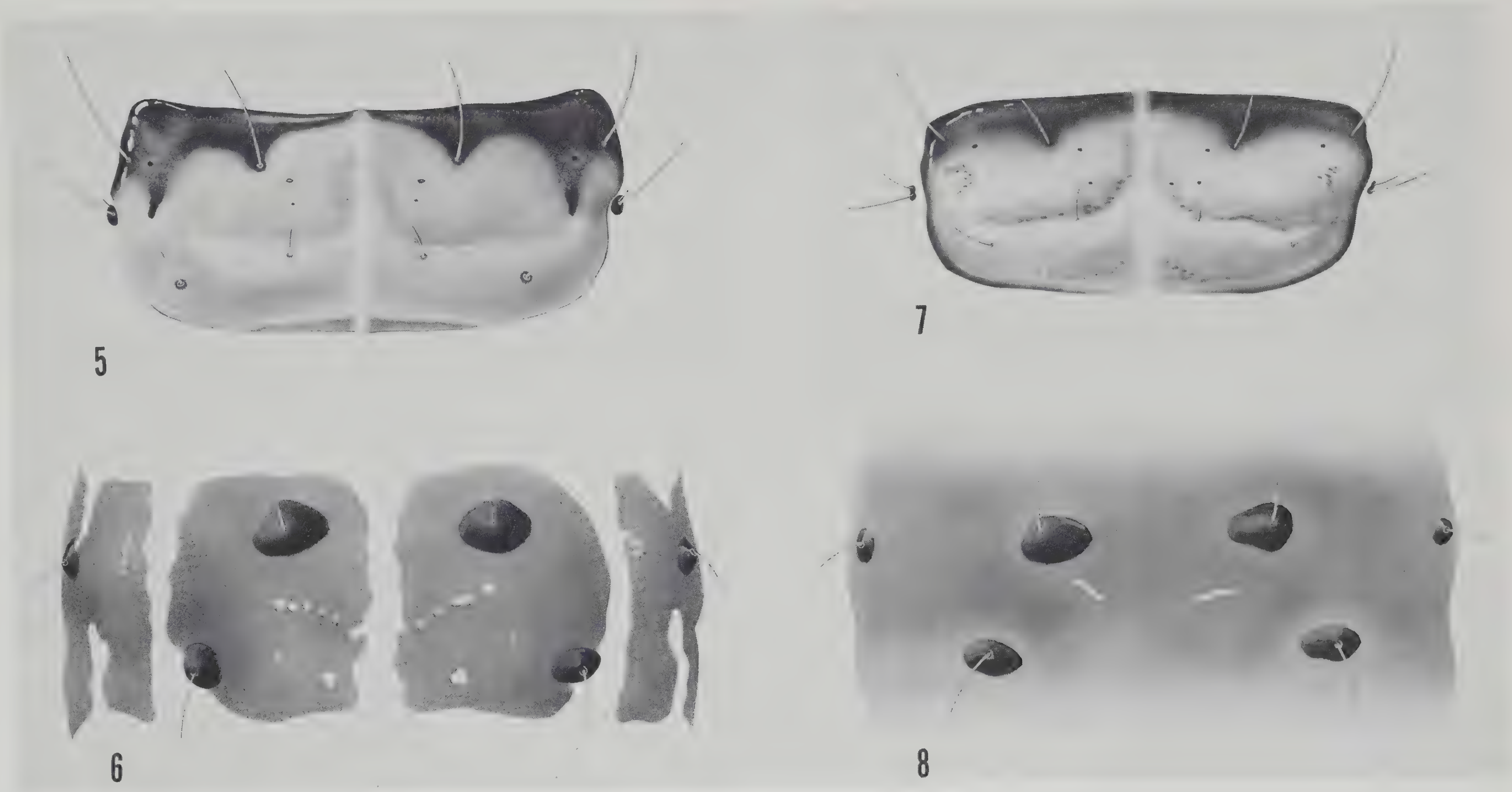
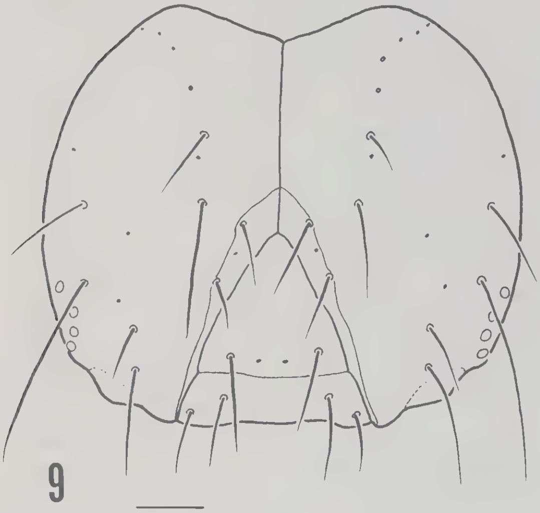


Fig. 5–8.—Dorsal views of cervical shields on prothoracic segments (top row) and third abdominal segments (bottom row) of larvae, showing differences of transverse banding. 5 and 6, *H. immanis*; 7 and 8, *H. micacea*.

1–3 slightly thickened, 4 merely setose; tarsal claw base reduced, weakly convex.

Abdomen. Segment Ab1 has 2 SV setae. Segments Ab2–6 have 3 SV setae each, 1 each on Ab7 and Ab8. Dorsal and lateral chaetotaxy of Ab6, Ab7 as in Fig. 17. Segment Ab9: SD1 semihairlike, much thinner and shorter than D1 and D2. Segment Ab10: posterior margin of anal shield entire, dorsal surface of anal shield evenly convex except for pinacula; subanal setae unmodified, subequal to lateral setae of anal proleg.

Coloration (in part, translated from Beck 1960).



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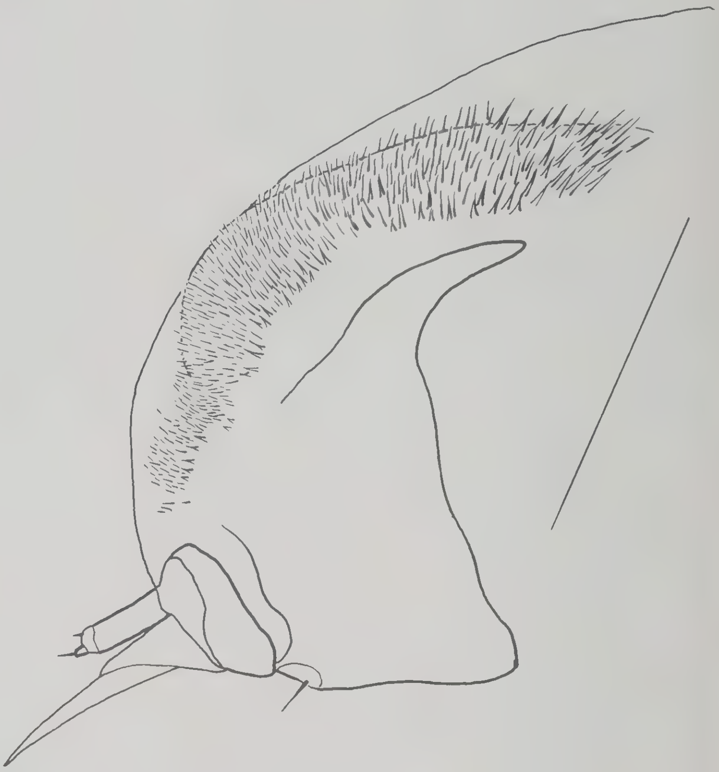

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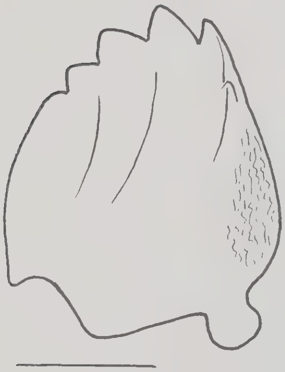

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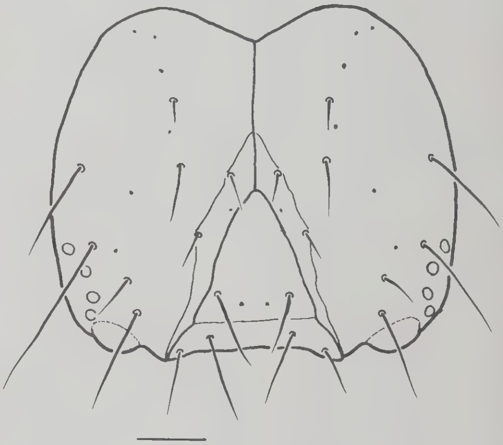

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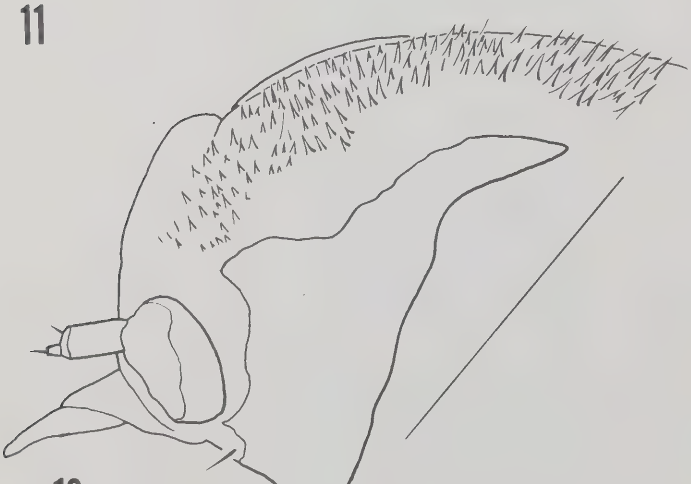

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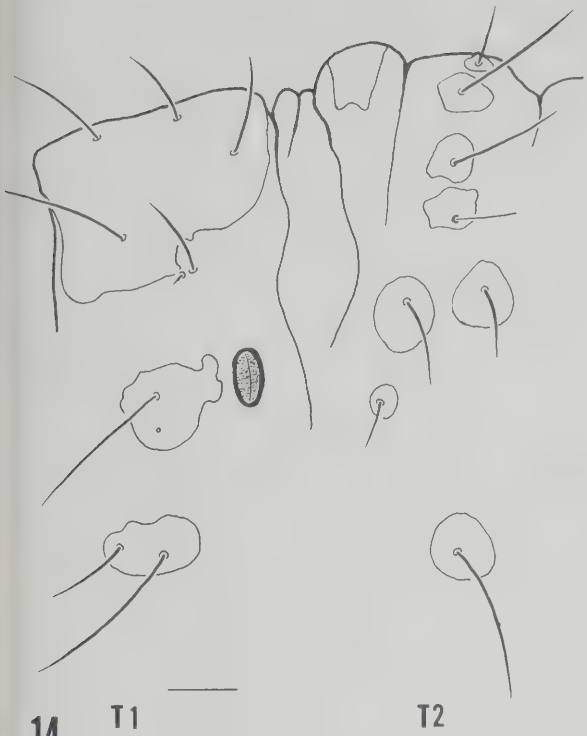
Fig. 9–11.—Mature *Hydraecia immanis* larva. 9, frontal view of head capsule; 10, left lateral view of hypopharyngeal complex; 11, oral surface of left mandible. Fig. 12 and 13.—Mature *H. micacea* larva. 12, frontal view of head capsule; 13, left lateral view of hypopharyngeal complex. Scale lines equal 0.5 mm.



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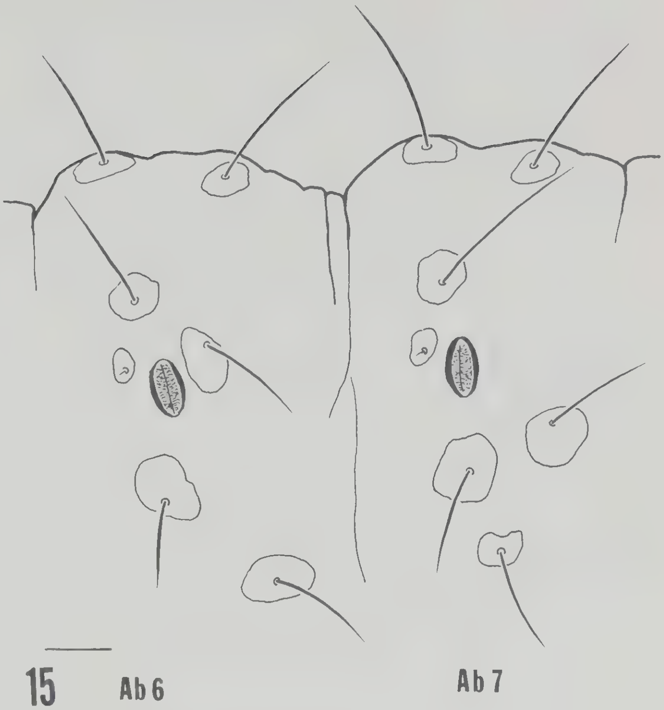

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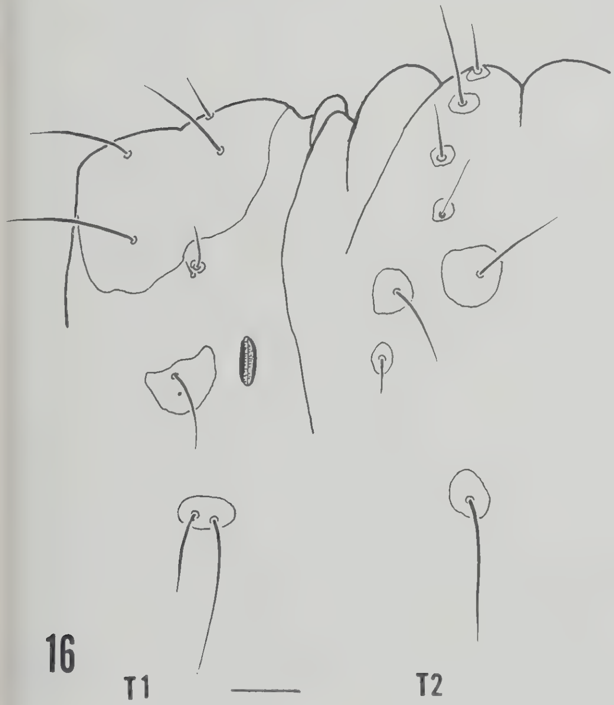

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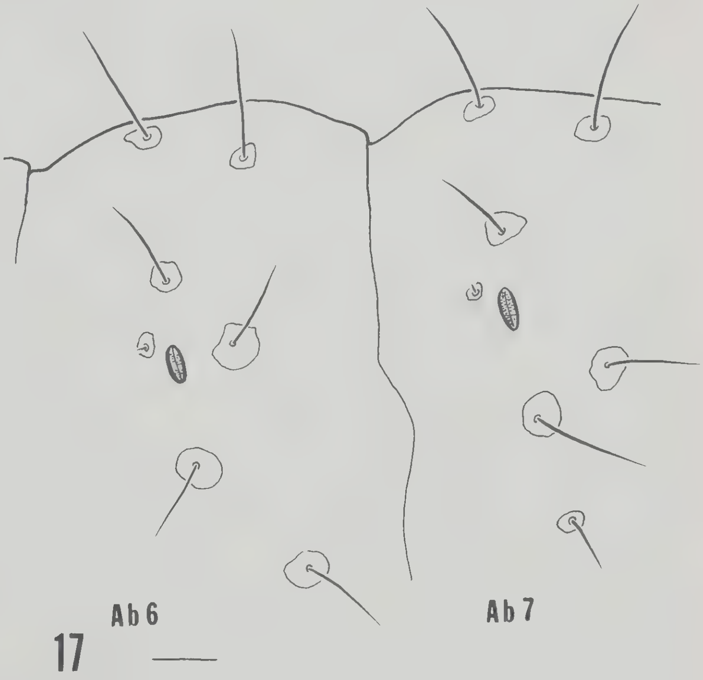

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Fig. 14 and 15.—Mature *Hydraecia immanis* larva. 14, prothoracic (T1) and mesothoracic (T2) segments (dorsolateral aspects); 15, sixth (Ab6) and seventh (Ab7) abdominal segments (dorsolateral aspects). Fig. 16 and 17.—Mature larva of *H. micacea*. 16, prothoracic and mesothoracic segments; 17, sixth and seventh abdominal segments. Scale lines equal 0.5 mm.

Head reddish brown, ocellar area slightly darker; mandibles dark brown to black. Body ground color whitish gray tinged with red, continuous transverse bands (Fig. 8); pinacula conspicuous, dark brown to black; cervical shield (Fig. 7) glossy, pale yellowish brown, with wide, dark brown anterior border, thin brownish lateral and posterior borders, thin whitish middorsal line. Anal shield varies from yellow to dark brown.

Material examined. NEW YORK: Monroe County, Hamlin, 8 June 1978, corn, A. A. Muka/M. E. Phillips, 4 larvae; Lewis County, near

Constableville, 6 June 1979, corn, J. G. Franclemont, 9 larvae. NEWFOUNDLAND: Lamaline, September 1976, boring in potato stem, 2 larvae. QUEBEC: Drummondville, 21 June 1978, boring in iris stem, 1 larva.

DISCUSSION

The ultimate instar larvae of *Hydraecia immanis* and *H. micacea* can most accurately be distinguished from each other by collectively examining the spinneret, hypopharynx, color pattern of the cervical shield, shape of the prothoracic spiracle, and dorsal transverse banding on the abdominal segments.

The spinneret of *H. immanis* is acutely pointed and the hypopharyngeal spines are very fine and numerous (Fig. 10). In contrast, *H. micacea* is characterized by having a bluntly tipped spinneret and stout spines on the hypopharynx that are less numerous (Fig. 13). The characteristics of the spinneret and hypopharynx remain unchanged in preserved specimens and can be seen easily with a dissecting microscope at 50–100X magnification after the removal or abduction of either mandible. Using these characteristics is disadvantageous if field-collected larvae must be kept alive.

The cervical shield of *H. immanis* has a dark anterior border that is wider laterally than medially (Fig. 5). This border on *H. micacea* (Fig. 7) is also dark but is nearly of equal width across the cervical shield and thinly extends around the lateral and posterior edges. The maculation of the cervical shields is useful for identifying living or freshly preserved larvae, but the thin, dark lateral and posterior borders on *H. micacea* can be difficult to see on old, poorly preserved specimens.

The prothoracic spiracle of *H. immanis* tends to be broadly elliptical (Fig. 14), while that of *H. micacea* is narrowly elliptical (Fig. 16). These differences can be used cautiously to diagnose either the living or preserved larvae of the two species but should not be used solely.

The transverse banding on the abdominal segments, as detailed in the above descriptions, is species specific and easily interpretable in living specimens at the onset of the ultimate larval instar. However, the diffuse, continuous transverse bands on *H. micacea* and the bands of *H. immanis,* which are interrupted by the middorsal and subdorsal lines, may be lost entirely shortly prior to the prepupal stage. It is the implied constancy of the interspecific differences of the transverse banding that presents difficulty in Crumb's (1956) identification key.

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LITERATURE CITED

Beck, H. 1960. Die Larvalsystematik der Eulen (Noctuidae). Abhandlungen zur Larvalsystematik der Insekten. No. 4. Akademie-Verlag, Berlin. 406 p.

Bethune, C. J. S. 1873. Insects affecting the hop. Pages 27–34 *in* Report of the Entomological Society of Ontario, 1872. Toronto.

Brittain, W. H. 1915. *Hydroecia micacea* as a garden pest. Nova Scotia Entomological Society Proceedings 1: 96–97.

———. 1918. Notes on two unusual garden pests in Nova Scotia. Pages 94–99 *in* Forty-eighth Annual Report of the Entomological Society of Ontario, 1917. Toronto.

Comstock, J. H. 1883. The hop-vine borer, or hop grub. American Agriculturist 42: 275.

Crumb, S. E. 1956. The larvae of the Phalaenidae. U.S. Department of Agriculture Technical Bulletin 1135. 356 p.

Forbes, W. T. M. 1954. Lepidoptera of New York and neighboring states. Noctuidae. Part 3. Cornell University Agricultural Experiment Station Memoir 329. 433 p.

Gibson, A. 1909. *Hydroecia micacea,* Esp. in Canada. Pages 49–51 *in* Thirty-ninth Annual Report of the Entomological Society of Ontario, 1908. Toronto.

Godfrey, G. L. 1972. A review and reclassification of larvae of the subfamily Hadeninae (Lepidoptera, Noctuidae) of America north of Mexico. U.S. Department of Agriculture Technical Bulletin 1450. 265 p.

Hawley, I. M. 1918. Insects injurious to the hop in New York with special reference to the hop grub and the hop redbug. Cornell University Agricultural Experiment Station Memoir 15:141–224.

Hitchcock, C. L., A. Cronquist, M. Ownbey, and J. W. Thompson. 1961. Vascular plants of the Pacific Northwest. Part 3: Saxifragaceae to Ericaceae. University of Washington Press, Seattle. 614 p.

Muka, A. A. 1976. A new corn pest is south of the border. Hoard's Dairyman 121:688.

Nye, I. W. B. 1975. The generic names of moths of the world. Vol. 1. Noctuoidea (part): Noctuidae, Agaristidae, and Nolidae. British Museum (Natural History), London. 568 p.

Tietz, H. M. 1972. An index to the described life histories, early stages and hosts of the macrolepidoptera of the continental United States and Canada. Part 1. Allyn Museum of Entomology, Sarasota, Florida. 536 p.

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ILLINOIS NATURAL HISTORY SURVEY
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Illinois Pheasants: Population, Ecology, Distribution, and Abundance, 1900-1978

Richard E. Warner

The history of the ring-necked pheasant *(Phasianus colchicus)* spans nearly a century in the Prairie State. Because this native of China is intimately associated with agriculture, trends in the bird's abundance have reflected patterns of land use and the general status of wildlife habitat in Illinois.

The pheasant is important for aesthetic, economic, and recreational reasons—particularly since the Illinois legislature established a season for hunting cock pheasants in 1915. In recent years this sport has created annually over one million recreational trips afield; revenue generated in Illinois by pheasant hunters, exclusive of license fees, has approached $20 million per year (Labisky 1975:3).

This publication reviews the establishment of pheasants in Illinois, subsequent patterns of distribution and abundance, and the effects of farming practices on pheasant populations; it considers pheasant numbers and distribution as monitored by annual estimates of cock harvests and by Rural Mail Carriers' Censuses (RMCC), which have been conducted every 5 years since 1958 (Labisky 1975); and it presents data from the Sibley Study Area (SSA) on trends in hunter success, numbers of pheasants, and land use. The SSA in east-central Illinois has been an important source of data on pheasants since the late 1940's.

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POPULATION ECOLOGY

Natality and Mortality

Hen pheasants reproduce one brood of chicks per year. The average nest of 8-10 eggs typically hatches in mid-June (Robertson 1958:76, Labisky 1968:75). During a normal life span of about 2 years (Wagner et al. 1965:69, Etter 1966:2-3) pheasants are exposed to factors that regulate survival and reproduction. Some of the factors that limit the distribution and abundance of ring-neck populations in Illinois follow.

Habitat

Unlike many avian species, the pheasant is nonmigratory; annual movements of ring-necks tracked by radio telemetry in east-central Illinois (Warner 1979) have typically encompassed a radius of less than 1 or 2 miles.

Certain features of habitat—the amount, growth forms, juxtaposition, and frequency of disturbance of vegetation—are particularly critical to pheasants for reproduction. In Illinois, fields of tame hay, hay pasture, and uncultivated areas with grassy and weedy forbs constitute prime nest cover (Robertson 1958:57, Labisky 1968:295, Joselyn et al. 1968:217). Oat fields planted as a nurse crop for legumes (alfalfa and red clover) and clipped in midsummer provide areas for broods to forage for insects (Warner 1975). The amount of safe nest and brood rearing cover may be a principal factor that limits numbers of pheasants in most parts of Illinois (Joselyn et al. 1968, Warner 1979).

Pheasants find protection from winter elements primarily in residual, herbaceous, and woody vegetation. In some sectors of the state, as in the east-central cash grain belt, protective cover in winter is nearly absent (Robertson 1958:19, Warner & David 1978). However, severe blizzards—precipitation accompanied by driving winds and below-zero (-10° - 20° F) temperatures—are less frequent in Illinois than in more northern Midwestern and Plains States (Labisky et al. 1964:12-13). In Illinois, pheasant mortality from winter storms has rarely been extensive (Robertson 1958:20, Warner & David 1978).

Waste grains scattered by harvest machinery is the mainstay of the adult pheasant diet in Illinois (Robertson 1958:18). Pheasants normally find waste grains even in

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plowed fields and deep snow (Leedy & Hicks 1945:57, Warner & David 1978:118).

Predators

Pheasants are particularly vulnerable to predation during nesting; the destruction of eggs by ground squirrels *(Citellus tridceemlineatus)*, skunks *(Memphitus memphitus)*, raccoons *(Procyon lotor)*, farm pets, farm machinery, and avian predators is relatively common (Labisky 1968:278, Joselyn et al. 1968:227). However, by initial or renesting attempts, up to 50-75 percent of the hens may be successful in hatching a nest (Robertson 1958:79, Labisky 1968:41) if nest cover is available. Juvenile pheasants are vulnerable to predation, particularly in the early weeks of life (Errington 1945:197).

Although some pheasants fall prey to foxes, hawks, owls, and other predators, there is no evidence that predation is a primary limiting factor to pheasant populations (Errington & Hamerstrom 1937, Allen 1954:250) when suitable nest cover exists.

Pheasant Distribution

Odum (1971:113) observed, "quite different factors may limit abundance in the center of ranges and distribution at the margins . . ." Although numerous pen-reared pheasants were planted in far western and southern counties of Illinois in the early 1900's (discussed later in this manuscript), self-reproducing populations have not become established (Labisky et al. 1964); yet habitat suitable for reproduction by pheasants appears relatively abundant in most unoccupied areas (Illinois Cooperative Crop Reporting Service 1978).

Several more recent attempts have been made to establish pheasants south of 39° north latitude in Illinois (Klimstra & Hankla 1953, Ellis & Anderson 1963, Anderson 1964, 1968). Robertson (1958:7) noted, "Recent observations of an experimental release in southern Illinois . . . re-emphasize the futility of stocking pheasants of the regular game farm strain . . ." Yeatter (1953) postulated that higher temperatures during incubation limited the southward spread of self-maintaining populations.

Experimental releases in western counties have generally failed, although establishment of localized populations (from relocated wild pheasants) may have succeeded (Brady 1974, Vinzant 1978).

The fertility and composition of biogenic salts vary among soil types and land formations in Illinois (Fehrenbacher et al. 1967, Jones et al. 1968). Allen (1954:20) noted, "Good soils yield the best crops, both in quantity and quality of practically everything that lives upon them."

Anderson & Stewart (1969:269) concluded:

> "If inorganic ions are limiting the distribution and abundance of pheasants in the Midwest, combinations of two or more elements . . . are possibly—if not probably—involved, and ions comprising such combinations possibly differ from one region to another."

A combination of stresses, such as unfavorable climate and the ingestion of biogenic salts, no doubt lowers the resistance of pheasants to extrinsic factors in marginal and unoccupied areas (Selye 1949:837; Labisky et al. 1964:13).

Pheasant Stocking

Early releases of pheasants in Illinois led to the establishment of wild (self-reproducing) populations. However, present-day stocking of pheasants to increase densities has been largely futile (Besadny & Wagner 1963). Errington (1945:202), with reference to stocking, remarked, "It may be fruitless if done indiscriminately and may have further disadvantages of being expensive, giving a false impression of accomplishment, and diverting attention from basic problems."

Pheasant numbers are regulated by certain factors of habitat. The release of pheasants in a given area where self-maintaining populations of pheasants exist can only result in compensatory increases in mortality. Hence, released pen-reared stock experience very low survival (high mortality) and typically negligible reproduction (Besadny & Wagner 1963).

Hunting

The male pheasant is a polygamous breeder, often associated with harems of 6-12 hens over the reproductive season (Labisky 1961). Harem formation results in the establishment of territories and maintenance of high fertility of females (Robertson 1958:47-48).

With polygamous breeding, the harvest of a high proportion of the available roosters by hunters does not inhibit successful reproduction by hens (Labisky 1961:13-14). Even in situations where more than 80 percent of the cocks are shot, egg fertility remains high (Allen 1947). In recent years (under existing constraints of seasons, bag limit, and low populations), less than one-half of the roosters have been bagged by hunters in east-central Illinois (Warner 1978:6). Greater proportions of cocks are typically harvested by hunters in years when pheasant numbers are relatively high than when numbers are low.

Thus, long-term trends in pheasant abundance are determined by environmental factors—principally climate, weather, soils, and land use—rather than the number of cocks taken in the hunter's bag.

METHODS

The early establishment and expansion of range occupied by pheasants in Illinois is reviewed in this manuscript from previous publications (Robertson 1958), unpublished records, and personal interviews. The findings of previous RMCC's were obtained from Greeley et al. (1962), Labisky & Anderson (1965), and Labisky (1975).

Sibley Study Area (SSA)

The relative abundance of pheasants and land use data for the SSA, located in Ford and McLean counties (Fig. 1), are presented in this manuscript. This area is

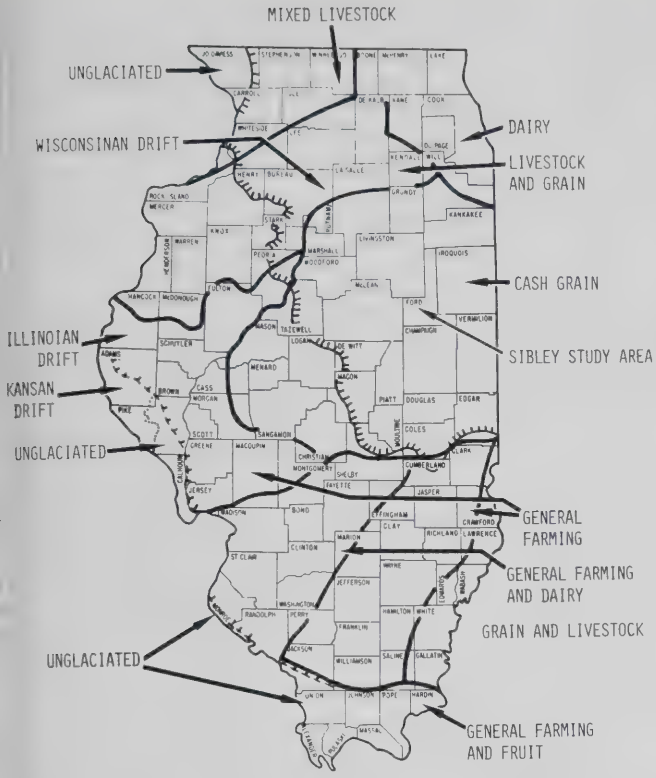

Fig. 1.—Major farm types by region in Illinois (after Preno & Labisky 1971, Ross & Case 1956), and location of Sibley Study Area.

intensively farmed for cash grains (Fig. 2); dominant slopes are about 0.4 percent and do not exceed 10 percent (Fehrenbacher et al. 1967). Depending upon drainage, subsoils range from loam till to silty clay and clay till or drift. The dark-colored, highly fertile prairie soils were developed on this loess over glacial drift of the last substage of the Wisconsinan glacial period (Fehrenbacher et al. 1967).

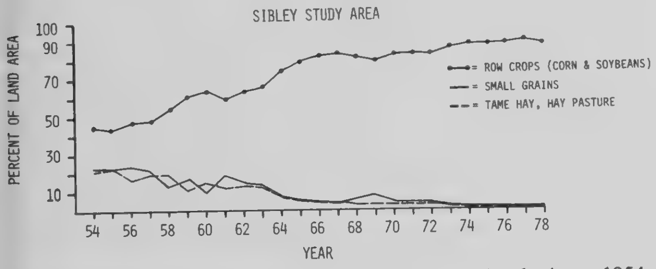

Fig. 2.—Land use by cover type on the Sibley Study Area, 1954-1978.

Land use on the SSA was determined annually by marking field types and boundaries on 8-inch aerial photographs and using an overlay grid to measure habitat acreage.

The abundance of pheasants on the SSA was monitored annually by several methods: spring breeding counts in May were made by recording all pheasants observed while driving transect routes, brood counts in July and August were made by recording all pheasants seen on roads and roadsides, hunter harvests were surveyed the opening weekend of upland game hunting season, and sex ratio and aerial counts (weather permitting) were made in late winter. Indices from the various counts were combined to calculate densities of pheasants per square mile (Fig. 3).

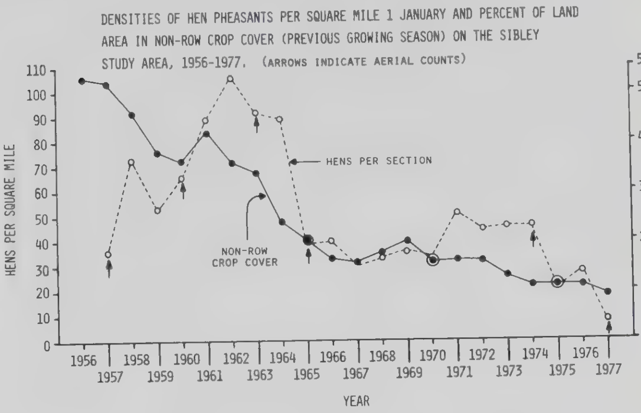

Fig. 3.—Densities of hen pheasants per square mile (January) and percent of land in nonrow crop farmland (previous growing season), on the Sibley Study Area, 1957-1978.

Rural Mail Carriers' Census (RMCC)

The 74 northernmost counties of Illinois, which encompass the known range of wild pheasants, were censused with the volunteer assistance of rural letter carriers during 24-28 April 1978.

Census cards with instruction packets were mailed to 623 post offices—1,178 rural letter carriers. As in previous RMCC's conducted at 5-year intervals (Labisky 1975), letter carriers drove their routes between 0700 and 1200 hours (CST) over the 5-day period and recorded on a census card for each route: name, post office, rural route number, length of route in miles, counties and political townships transected by the route, and cocks and hens observed. Even if no pheasants were observed, rural letter carriers were asked to return the census card. Follow-up mailings were not made to post offices if census cards were not returned.

Census data were encoded on IBM cards for computer manipulation. Programs were developed to perform calculations using the University of Illinois' "CYBER" interactive computer system. Indices of abundance were computed for townships, counties, and the entire range by dividing the number of pheasants observed by miles driven; multiplication of the dividend by 100 yielded an index of pheasants observed per 100 miles. An Illinois Geological Survey computer program ("Illioplot") was modified to print maps by plotting numerical and symbolic indices of abundance in each township.

If a given rural letter delivery route transected two or more townships (or counties), the pheasants observed and miles driven were divided equally and assigned to townships reported on the census card.

FINDINGS

Nineteenth-Century Agriculture

When the first releases of pheasants were made in Illinois (during the late 1800's), the landscape into which the exotic ring-neck was introduced had been radically altered by post-Civil War agricultural development (Vestal 1931, Schlebecker 1975). By 1880 nearly all prairie sod in Illinois had been plowed for cultivation (Yeatter 1957).

With the elimination of diverse prairie flora, habitat available to native fauna was modified and reduced. Prairie grouse *(Tympanuchus cupido)* occupied an ecological niche in the prairie community similar to the ground-nesting pheasant. Following a peak in numbers in the mid-1800's (Yeatter 1957), the greater prairie chicken was extirpated from much of its range in Illinois by intensified agriculture (Yeatter 1943:379). During this era of receding populations of prairie chickens, the ring-necked pheasant became established in the Prairie State.

A historical sketch of a farm on the SSA illustrates the dynamics of this transition in Illinois: In 1880, Curtis Henry Stein, a tenant farmer on the SSA aided by neighbors, hitched a team of oxen to a cable winch and V-plow, and drained and plowed the prairie marsh located on his "south 40."

In 1926, Walter O. Stein, grandson of Curtis, rented his first farm in the area. A knoll on his farm served as a spring booming ground for prairie chickens. However, before Walter Stein completed a 4-year rotation of oats-clover-pasture-corn on his farm, the prairie chickens were gone. Mr. Stein recollected, "We started seeing pheasants on our farm at about the time we saw no more prairie chickens."[1]

Early Pheasant Releases

Pheasants were first successfully released in the United States in Oregon, New England, and the North Atlantic States after 1880 (Walcott 1945:3; Bennett 1945:11). The initial known release in Illinois was shortly thereafter; numerous individuals attempted releases in Illinois around the turn of the century (Robertson 1958:3). In 1906 the State Game Department received 5,500 pheasant eggs (Phillips 1928:44) to be hatched and distributed to sportsmen's clubs and farmers. State-proffered releases flourished from 1906 to 1918 and then were discontinued until 1928 (Osborne 1943:12, Robertson 1958:3), when the newly formed Department of Conservation again made stock for releasing available to the public. Robertson (1958:4) estimated that all releases, state and private, made in Illinois up to 1928 totalled around 10,000 pheasants. Leopold (1931:106) indicated that most known releases of pheasants through the mid-1920's were in northeastern, central, and western counties, and in Mississippi lowlands along the southern two-thirds of the state.

Genetic Ancestry

Based on the wide color variation of wild pheasants, Yeatter (1953:5-6) hypothesized that the ring-neck populations in Illinois have a diverse ancestry. Robertson (1958:3) noted that some stock was shipped from the Pacific Northwest; other populations were progeny of captive breeding birds in Europe. The diversity of introduced stock indicates that wild pheasants in this state have genetic ancestry from at least four types of pheasants (Labisky 1968:3): *P. colchichus colchicus* (Caucasus pheasant of black-necked group); *P. c. torquatus* (Chinese ring-necked pheasant of grey-rumped group); *P. c. mongolicus* (Kirghiz pheasant of kirghiz group); and *P. versicolor* (Japanese green pheasant).

Range Expansion 1900-1930

From 1906 to 1909 Stephen A. Forbes directed a survey of land birds in Illinois (Forbes & Gross 1923:438-447); pheasants were not recorded on the list of species observed. However, shortly after 1910, small numbers of pheasants appeared in parts of their present range (Robertson 1958:7). By the 1920's systematic releases had been attempted in every county (McAtee 1929:5, Fig. 4), and patterns of establishment were becoming apparent. Leopold's game survey in 1928-1929 (Leopold 1931:106) indicated that wild populations were established in the northeastern counties—McHenry, Lake, Kane, Cook, Du Page, Will, and Kankakee—with peripheral populations in the adjacent counties of Boone and DeKalb. Scattered populations in the adjacent counties of Boone and DeKalb. Scattered populations also were noted in east-central counties (Leopold 1931:106). In an unpublished manuscript, Leopold mentioned the existence of scattered flocks along the Illinois River bottom west as far as Scott County, and along creek bottoms in Sangamon, Macoupin, and Greene Counties (Robertson 1958:10).

Pheasants were apparently increasing in numbers in east-central counties by the late 1920's. Walter O. Stein first observed pheasants around Sibley (Ford County) about 1927. Robertson (1958:10) in reviewing Christmas bird censuses from 1908 to 1929 near Rantoul (Champaign County) and Paxton (Ford County) noted that pheasants were sighted once in 21 counts; four were seen December 24, 1925 (Ekblaw & Ekblaw 1926:44).

Through the 1920's pheasants were absent from most northwestern, western, and southern counties. Dr. N. R. Huff, president of the Southern Illinois Sportsmen's Association, told Leopold (1931:109): "Pheasants do not thrive south of the 39th parallel. They have been planted in southern Illinois . . . for 15 years but are not established anywhere that I know of."

In the early 1930's the DOC typically released approximately 8,000 pheasants each year, and distributed an equal number of eggs to farmers and sportsmen (Robertson 1958:4). Distribution of eggs was curtailed after 1932, but in 1937 the Cooperative Chick Program was formed by the DOC to make day-old chicks available to sportsmen's clubs (Schwartz 1950:20, Robertson 1958:45). This program continues and resulted in the distribution of over 32,000 chicks in 1977 (R. V. Bauer, DOC, personal communication 14 December 1978). Beginning in the 1930's state-proffered stock was distributed mainly to areas where pheasants were known to be established (Robertson 1958:7).

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[1] Information regarding the Stein farm was acquired from a personal interview with Walter O. Stein on November 8, 1978.

Distribution and Relative Abundance, 1930-1940

In the late 1920's and early 1930's the wild pheasant range expanded in the northern counties and throughout the east-central sector. Scattered populations were found in west/southwest and east/southeast counties, adjacent to the established range.

This range expansion can be seen by comparing the distribution and abundance of pheasants as mapped in 1929 by Leopold (Fig. 4) and in 1937 by Mohr (Fig. 5). By the late 1930's a center of abundance was clearly defined, encompassing the northeastern counties—Boone, De Kalb, Du Page, Kane, Kendall, Lake, and McHenry (Fig. 5). Densities of pheasants in east-central Illinois (Ford and Livingston counties) may have approached the numbers in the northeastern sector. Yeatter believed that pheasants were relatively well established in Champaign and surrounding counties in the 1930's (Robertson 1958:10).

In this era, wild pheasants were most abundant in Illinois' dairy region, with moderate numbers in the highly fertile east-central grain farming region (Ross & Case 1956, Fig. 1).

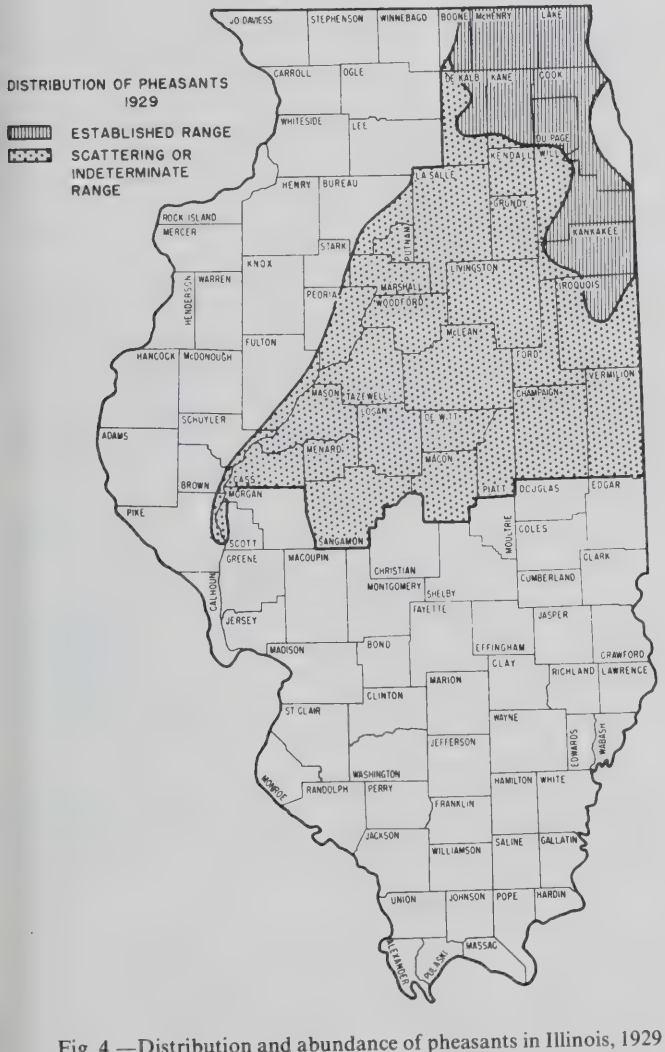

Fig. 4.—Distribution and abundance of pheasants in Illinois, 1929 (modified from Leopold 1931:106, Greeley et al. 1962:13).

Distribution and Abundance, 1940-1950

Following range expansion and rapid increase in numbers of pheasants in Illinois in the 1930's, pheasant populations suffered a notable decline, particularly from 1942 to 1945 (Robertson 1958:122). Declines occurred in most Midwestern states during this era (Kimball 1948:291-293, Allen 1953:125-128). In Illinois, the reduction in numbers has been partially attributed to adverse spring weather (Robertson 1958:122-123, Labisky et al. 1964:13).

In 1948, a second survey of hunter success in Illinois (Robertson 1958) (Fig. 5) suggested a state-wide upswing in numbers of pheasants since the early 1940's, particularly in the northeastern and east-central regions (Robertson 1958:120). From 1937 to 1948, both these centers of abundance expanded. Populations in peripheral areas of the range, however (notably along the southwestern and southern edges), appeared lower in the 1940's than in the 1930's.

Yeager (1947:8, 9) described pursuit of the ring-neck by hunters in the prime northeastern range in the late 1940's:

> "In metropolitan Chicago, literally under the noses of 4,000,000 hurrying souls, there is some pheasant hunting . . . enough to take, within commuting distance of the Loop, 100,000 sportsmen afield . . . . Cover of better quality or interspersion is rare . . . . The several types of cover met all ring-neck needs: weed fields, ditch banks, and fencerows for nesting . . . dense thickets and briar patches for escape; and the best in cattail and slough-grass marsh for winter roosting."

During this era, ring-necks were widely hunted, particularly in northern and east-central counties; Livingston and De Kalb counties probably sustained the greatest densities of pheasants in the state (Yeatter & Yeager 1945:6, 36).

Distribution and Abundance 1950's

The surge in Illinois pheasant populations that began in the mid-to-late 1940's continued through the early 1950's. Robertson (1958:120) documented annual increases in numbers of pheasants on study areas in Stephenson, Winnebago, Kendall, De Kalb, Ford, and Livingston counties. A hunter survey in 1950 (Marquardt & Scott 1952, Greeley et al. 1962:14) suggested a moderate increase in numbers state-wide from 1948. The major centers of abundance continued to be north/northeastern and east-central counties. Hunter success in 1950 along the periphery of the established range was clearly improved over 1948 (Marquardt & Scott 1952, Greeley et al. 1962:14).

In 1951, the Illinois pheasant population may have peaked. Robertson (1958:120) estimated spring densities of about 60 pheasants per square mile in the northern range, and nearly 150 birds per square mile in representative portions of the east-central range (Ford and Livingston counties).

Pheasant numbers declined moderately in Illinois during the mid-1950's. A comparison of hunter success in

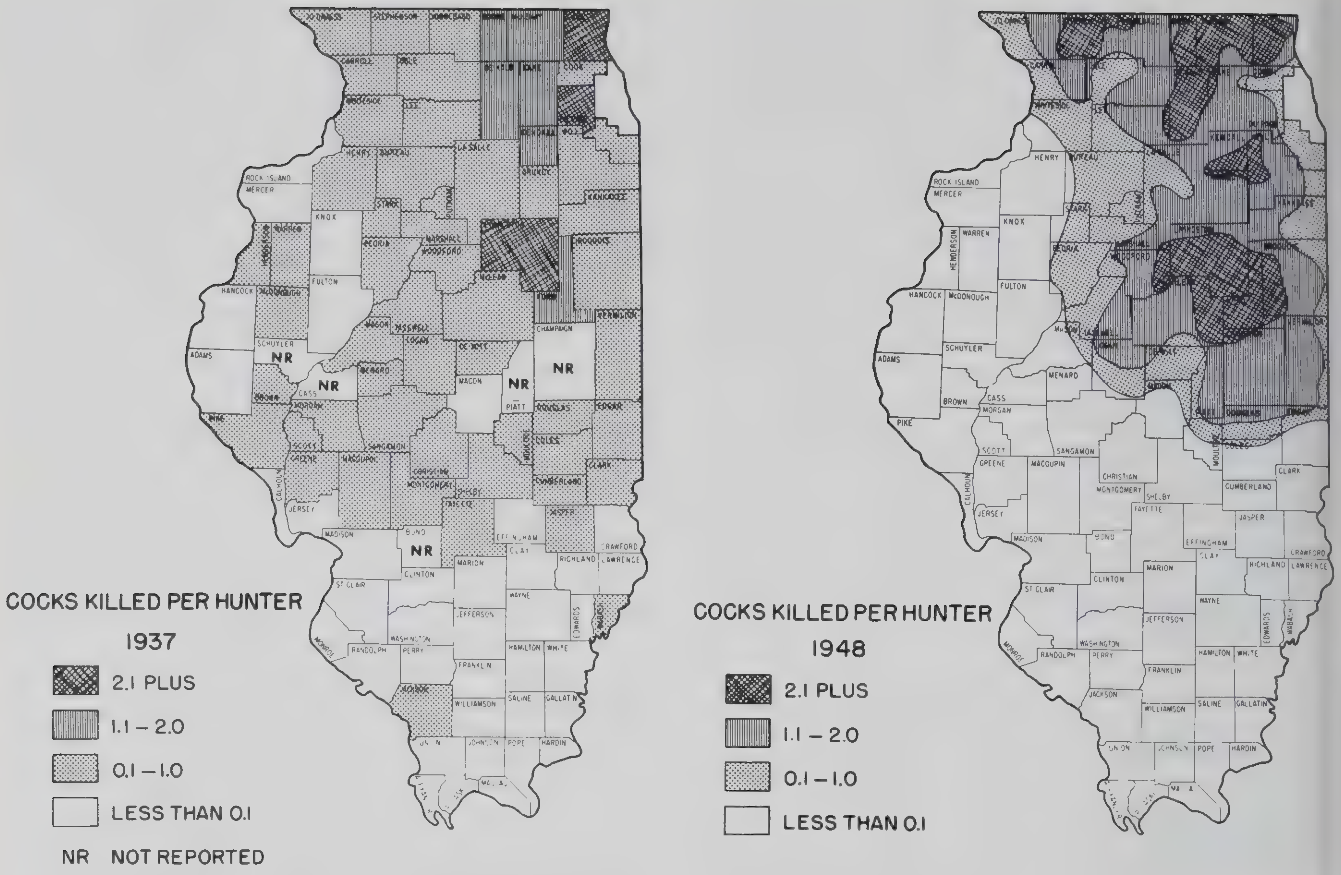

Fig. 5.—Distribution and abundance of pheasants in Illinois from hunting license questionnaires for 1937 (after Carl O. Mohr, unpublished) and 1948 (after Robertson 1958:9).

1950 (Marquardt & Scott 1952, Greeley et al. 1962) and the first RMCC in 1957-1958 (Fig. 6)—although different census methods—suggests notable declines in northern counties. Thus, by the early 1950's the major center of abundance was the east-central region; Livingston, Ford, Iroquois, McLean, and Champaign counties ranked at the top in respective order of abundance (Fig. 6). Trends in pheasant abundance on the SSA (Fig. 3) in Ford and McLean counties were representative of the prime range.

Pheasant Harvest.—The hunter kill of cock pheasants in the early 1950's is not clear. McCabe et al. (1956:298) estimated the pheasant kill for Illinois in 1950 at 150,000 pheasants—a figure that Robertson (1958:5) considered "much too low." The DOC estimated from license stub kill cards that an average of over 750,000 cocks were bagged annually, 1956-1959 (Table 1). Marquardt & Scott (1952:4) noted that this estimation technique is inherently high.

Land Use.—Changing patterns of land use were evident in Illinois in the 1950's. Acreage planted to hay and small grains (prime habitat for pheasant reproduction) peaked from 1948 to 1953 and declined precipitously thereafter as more acres were planted to corn and soybeans (Fig. 7). These land use changes were particularly evident in the east-central cash grain region (Fig. 7 and 8). Land use trends on the SSA are representative of these changes (Figs. 3, 7). The decline in hay and small grain cover beginning in 1954 was in part due to policy changes in the Agricultural Conservation Program (ACP), which through 1953 paid relatively large premiums to divert cropland from soil-depleting to soil-conserving crops (Held & Clawson 1965:183).

Labisky et al. (1964:8) characterized the optimal pheasant range in the Prairie State in the era of the late 1950's:

> "In summary, the following factors of land use were found to be characteristic . . . where pheasants were most abundant: (i) a high proportion of land area in cultivated crops and a low proportion in woodland, (ii) a high proportion of the farms classified as cash-grain farms and a lower proportion as dairy farms and livestock farms, and (iii) about 50 percent of the cropland in row crops (corn and soybeans), about 5 percent in hay, and about 15 percent in pasture."

Table 1.—Estimated harvest of cock pheasants during upland game seasons in Illinois averaged for specified periods.

PERIOD	AVERAGE ESTIMATED KILL	SOURCE
1956 - 1959	767,000	Preno and Labisky 1971
1960 - 1964	907,000	Preno and Labisky 1971
1965 - 1969	700,000	Preno and Labisky 1971
1970 - 1974	810,000	J. A. Ellis, personal communication
1975 - 1978	522,000	Ellis 1978, personal communication

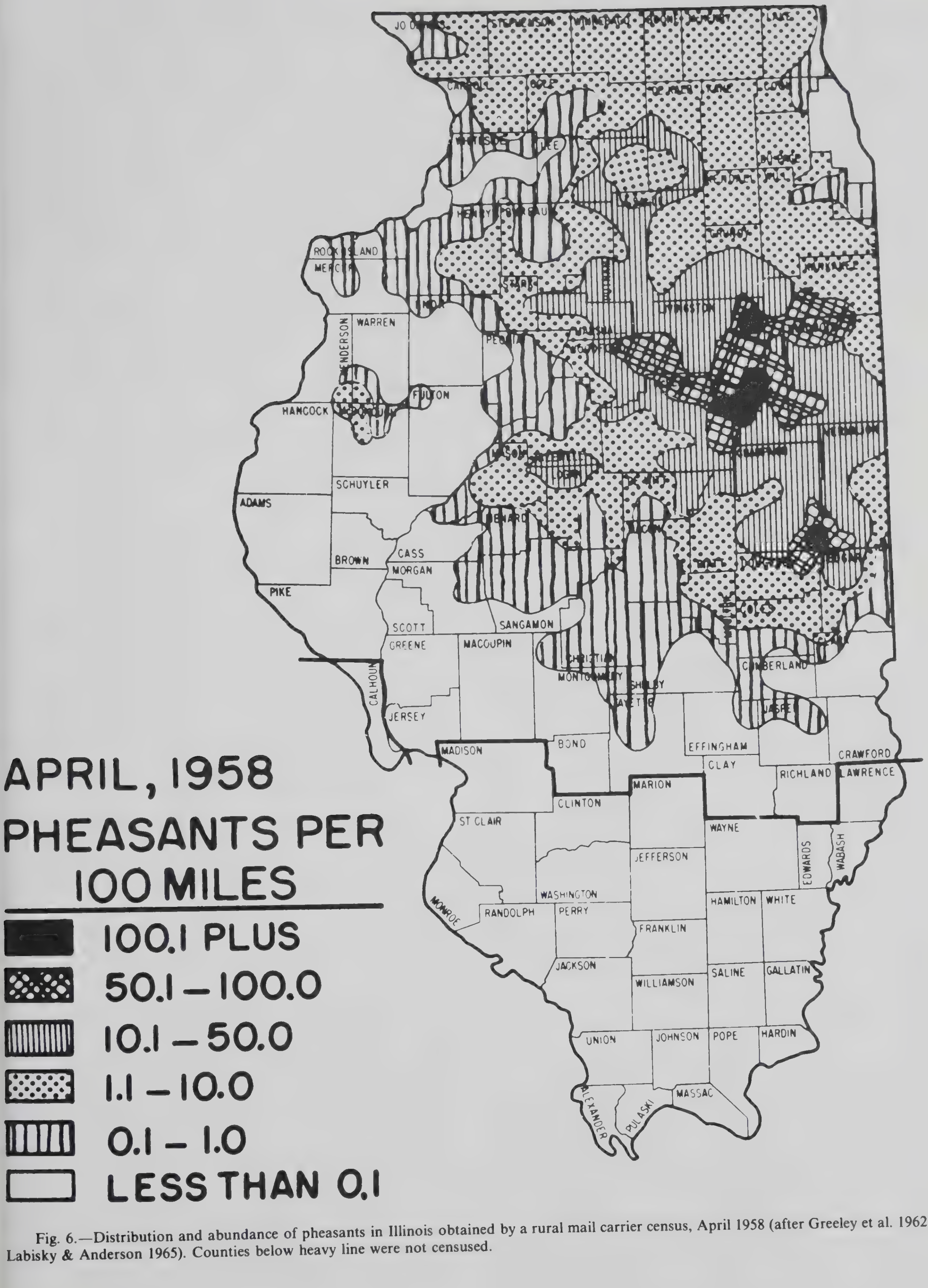

Fig. 6.—Distribution and abundance of pheasants in Illinois obtained by a rural mail carrier census, April 1958 (after Greeley et al. 1962, Labisky & Anderson 1965). Counties below heavy line were not censused.

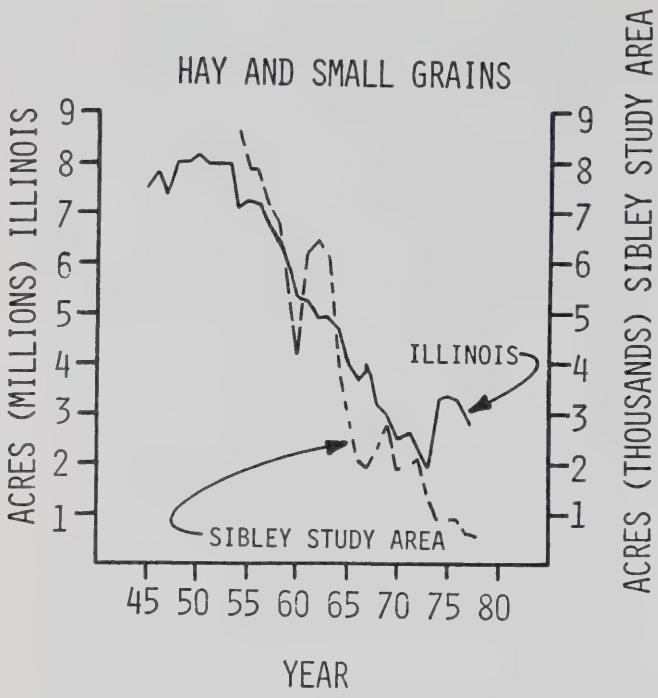

Fig. 7.—Acreages of hay and small grains planted in Illinois (state-wide) and the Sibley Study Area, 1945-1977 (state-wide data from Illinois Cooperative Crop Reporting Service).

Distribution and Abundance 1960-1970

The numbers of pheasants observed per 100 miles declined state-wide from the 1958 RMCC's (Fig. 6, Table 2) to the 1963 RMCC (Fig. 9). In the prime range (east-central counties, Table 3), however, densities of pheasants increased during these 5 years. Numbers of pheasants on the SSA apparently peaked in 1962 (Fig. 3) Declines were most evident in the early center of abundance in northern Illinois (Fig. 9).

The 1968 RMCC (Fig. 10) indicated a 28-percent decline in pheasant numbers from 1958 to 1968 and a 44 percent decline from 1963 to 1968 (Table 2). The most significant change in the late 1960's was the decline in the abundance of ring-necks in the east-central prime range (Fig. 9, 10: Table 3). Pheasant populations increased moderately in northwestern counties—especially Carroll, Ogle, and Whiteside—and in some counties in west/southwest and east/southeast sectors, especially Logan, Moultrie, De Witt, and Piatt (Fig. 10).

The 1968 RMCC also indicated localized increases in pheasant numbers around the joining of Vermilion, Edgar, Douglas, and Champaign counties, and at the junction of Mason and Tazewell counties (highest densities in the state) (Fig. 10).

Pheasant Harvest.—The estimated hunter harvest of cock pheasants in Illinois averaged 907,000 per season from 1960 to 1964 and 700,000 per season from 1965 to 1969 (Table 1). This estimated kill peaked at over 1 million birds in 1962 and 1963 and declined thereafter except for a harvest of over 900,000 in 1969 (Preno & Labisky 1971:20). Hunter surveys on the SSA during opening weekend of the upland game seasons show a marked increase in effort expended per cock bagged during the late 1960's (Fig. 11).

Land Use.—In the early 1960's, farmers were induced by a Federal Feed Grain Program (FFGP) to reduce acreages planted in corn and grain sorghums (Spitze 1972). Implementation of the FFGP arrested the expansion of row cropping for a few years (Fig. 3, 7) and resulted in moderately increased hay and oats acreages (Joselyn & Warnock 1964:549). The effects of the FFGP were most evident in the cash grain belt, represented by the SSA (Fig. 7). Although the FFGP did not result in vast increases in prime reproductive habitat for pheasants state-wide, moderate increases in the fertile cash grain belt were noted in undisturbed cover—predominately an oats-hay complex.

With the termination of the FFGP in the late 1960's (Spitze 1972) farmland devoted to forage legumes and small grains was further reduced and corn and soybean production increased (Fig. 3, 7). The west, west/south-west, and east/southeast counties were least affected by the surge in row crop production; conversion to row crop

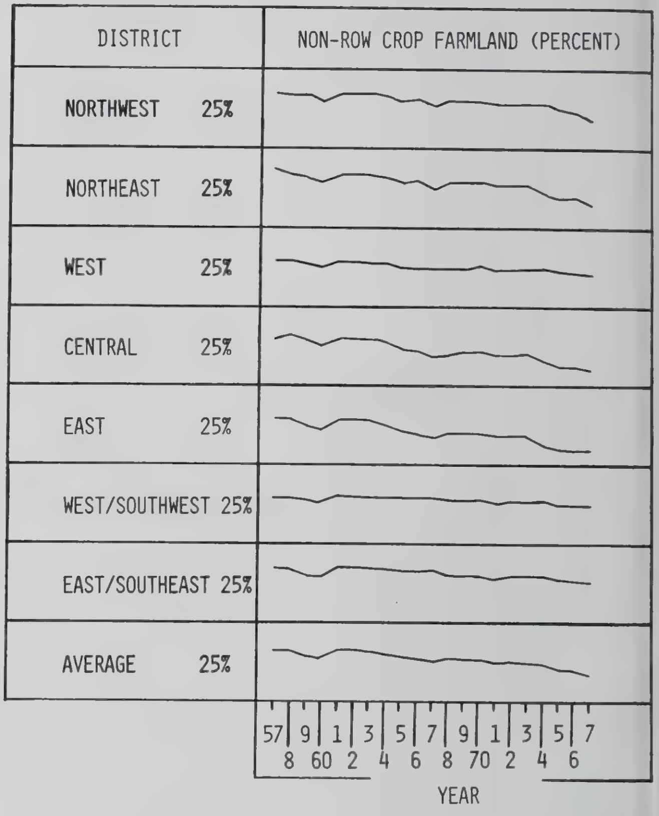

Fig. 8.—Nonrow-crop farmland by region in the Illinois pheasant range, 1957-1977. Regions are: **Northwest:** Bureau, Carroll, Henry, Jo Daviess, Lee, Mercer, Ogle, Putnam, Rock Island, Stephenson, Whiteside, and Winnebago counties. **Northeast:** Boone, Cook, De Kalb, Du Page, Grundy, Kane, Kendall, Lake, La Salle, McHenry, and Will counties. **West:** Adams, Brown, Fulton, Hancock, Henderson Knox, McDonough, Schuyler, and Warren counties. **Central:** DeWitt, Logan, McLean, Macon, Marshall, Mason, Menard, Peoria, Stark, Tazewell, and Woodford counties. **East:** Champaign, Ford, Iroquois, Kankakee, Livingston, Piatt, and Vermilion counties. **West/Southwest:** Bond, Calhoun, Cass, Christian, Greene, Jersey, Macoupin, Madison, Montgomery, Morgan, Pike, Sangamon, and Scott counties. **East/Southeast:** Clark, Clay, Coles, Crawford, Cumberland, Douglas, Edgar, Effingham, Fayette, Jasper, Lawrence, Marion, Moultrie, Richland, and Shelby counties. (Illinois Cooperative Crop Reporting Service 1978).

Table 2.—Comparative statistics obtained from rural mail carrier censuses of pheasants in the 74 northernmost counties (including 1,257 townships) of Illinois during designated 5-day census periods in April 1958, 1963, 1968, 1973, and 1978 (data from 1958-1973 after Labisky 1975).

CATEGORY	1958	1963	1968	1973	1978
QUESTIONNAIRES					
Number mailed	1,368	1,320	1,256	1,207	1,178
Number returned	1,053 (77)	1,202 (91)	1,143 (91)	1,120 (93)	1,061 (90)
Number usable	. . .	1,150 (87)	1,105 (88)	1,078 (89)	1,046 (89)
Number of townships reported (of 1,257)	1,221 (97)	1,222 (97)	1,214 (97)	1,199 (95)	1,193 (95)
Total miles driven	250,129	318,605	333,070	351,150	366,348
Miles driven per township reported	205	261	268	281	307
Cocks observed	10,047	17,204	10,706	10,898	1,651
Hens observed	9,044	14,446	7,545	6,454	1,390
TOTAL PHEASANTS OBSERVED	19,091	31,650	18,251	17,352	3,041
Sex ratio: hens per cock	0.9	0.8	0.7	0.6	0.8
Cocks per 100 miles	4.0	5.4	3.2	3.1	0.5
Hens per 100 miles	3.6	4.5	2.3	1.8	0.4
TOTAL PHEASANTS PER 100 MILES	7.6	9.9	5.5	4.9	0.9

Percentages are given in parentheses.

farming was most dramatic in the east and central sectors (Fig. 8).

Distribution and Abundance 1970's

By 1973 the relative abundance of ring-neck populations had declined 11 percent from 1968 as indicated by the RMCC's (Table 2). Although continuing to evidence substantial declines, the east-central counties ranked above other regions of the state in pheasants observed per 100 miles. Of these counties, the west/southwest counties (Logan, Moultrie, De Witt, Macon, and Piatt) were among the top 10 in 1973 (Table 3). Several neighboring counties had moderate increases in the early 1970's (Fig. 10, 12).

Trends in pheasant abundance were also changing in northern counties. Labisky (1975:7) observed:

> "Thus, despite some declines in pheasant abundance in De Kalb, McHenry, La Salle, Will, and Grundy Counties, northern Illinois posted a notable increase in pheasant abundance between 1968 and 1973, the first real upswing in pheasant numbers in this portion of the state in more than two decades. However, . . . pheasant abundance in northern Illinois was only about one-fifth of that in east-central Illinois."

Labisky (1975:7-8) characterized the western periphery of Illinois' ring-neck range: "small, scattered flocks of pheasants . . . which have never demonstrated strong geographic permanence or numerical persistence, have been maintained, at least partially, by sporadic releases of propagated pheasants." Labisky (1975:7) concluded that there had been no change in range occupied by pheasants in Illinois in over two decades.

The April 1978 RMCC denoted a decline of 84 percent in pheasants observed range-wide from 1973 (Table 2) and a decline of 92 percent from 1963 to 1978.

The magnitude of declines, in respective order, was greatest for the east-central, northern, and west/southwestern counties (Fig. 13). Populations of pheasants in counties peripheral to the established range tended to be stable from 1973 to 1978 although a slight-to-moderate increase in abundance was registered for Mercer, Cumberland, McDonough, Warren, Fayette, Hancock, Jasper, Jersey, Crawford, Greene, and Bond counties (Table 3). The 1978 census (Fig. 14), compared with previous RMCC's, indicates possible limited range expansion in Knox, Warren, Henderson, Fulton, and Schuyler counties, which may in part explain more frequent sightings in 1978 for these counties.

A precursory glance at the 1978 distribution map (Fig. 14) compared with 1973 (Fig. 12) suggests a moderate southward expansion of range by pheasants in counties along the southern apron. This expansion is particularly evident in the southernmost townships of Effingham and Jasper counties (Fig. 14). Researchers on prairie chicken sanctuaries in southern Jasper County confirm the presence and recent increase in numbers of pheasants in this area (R. L. Westemeier, Illinois Natural History Survey, personal communication). However, fewer pheasants were observed per 100 miles of driving in Jasper and Effingham counties in 1978 than in the late 1950's (Fig. 14). Censuses of 1957 and 1958 (Greeley et al. 1962:12) registered pheasants in all townships of Jasper County and nearly all townships of Effingham County. Pheasants were also observed in northern townships of Clay County (south of Effingham County) during this era.

Long-term population data (1958-1978) from the RMCC's for counties along the southern margin of the pheasant range—Bond, Clark, Clay, Crawford, Cumberland, Effingham, Fayette, Jasper, and Shelby—show that the number of townships in which pheasants were observed has declined in the 1973 and 1978 censuses. Of the townships in these counties, 26 had recordings of pheasants sighted during the first three RMCC's (1958-1968) but none in the 1973 or 1978 RMCC; only eight townships (generally in the north) had pheasants recorded for the first time in 1973 or 1978; and 26

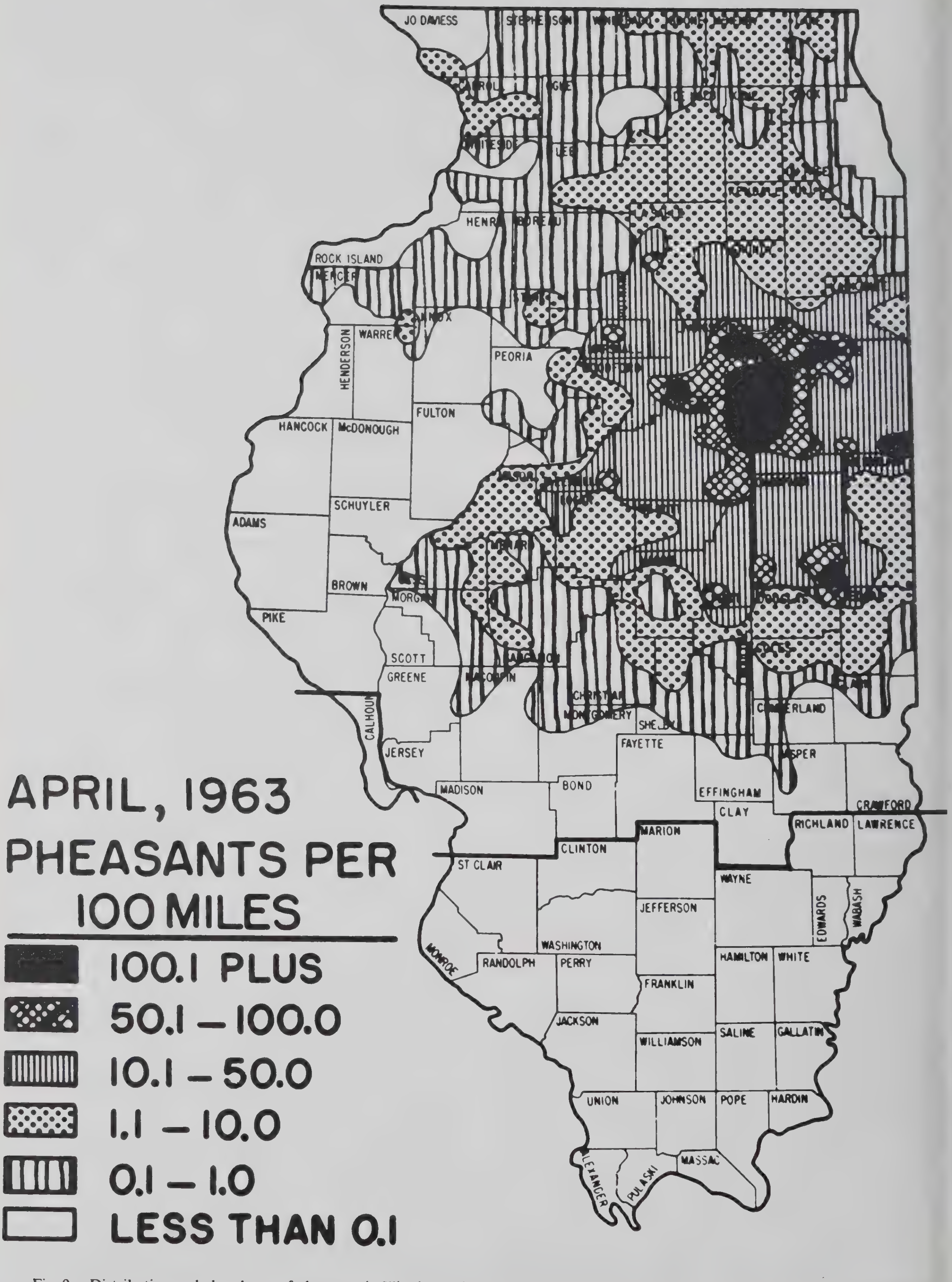

Fig. 9.—Distribution and abundance of pheasants in Illinois obtained by a rural mail carrier census, April 1963 (after Labisky & Anderson 1965). Counties below the heavy line were not censused.

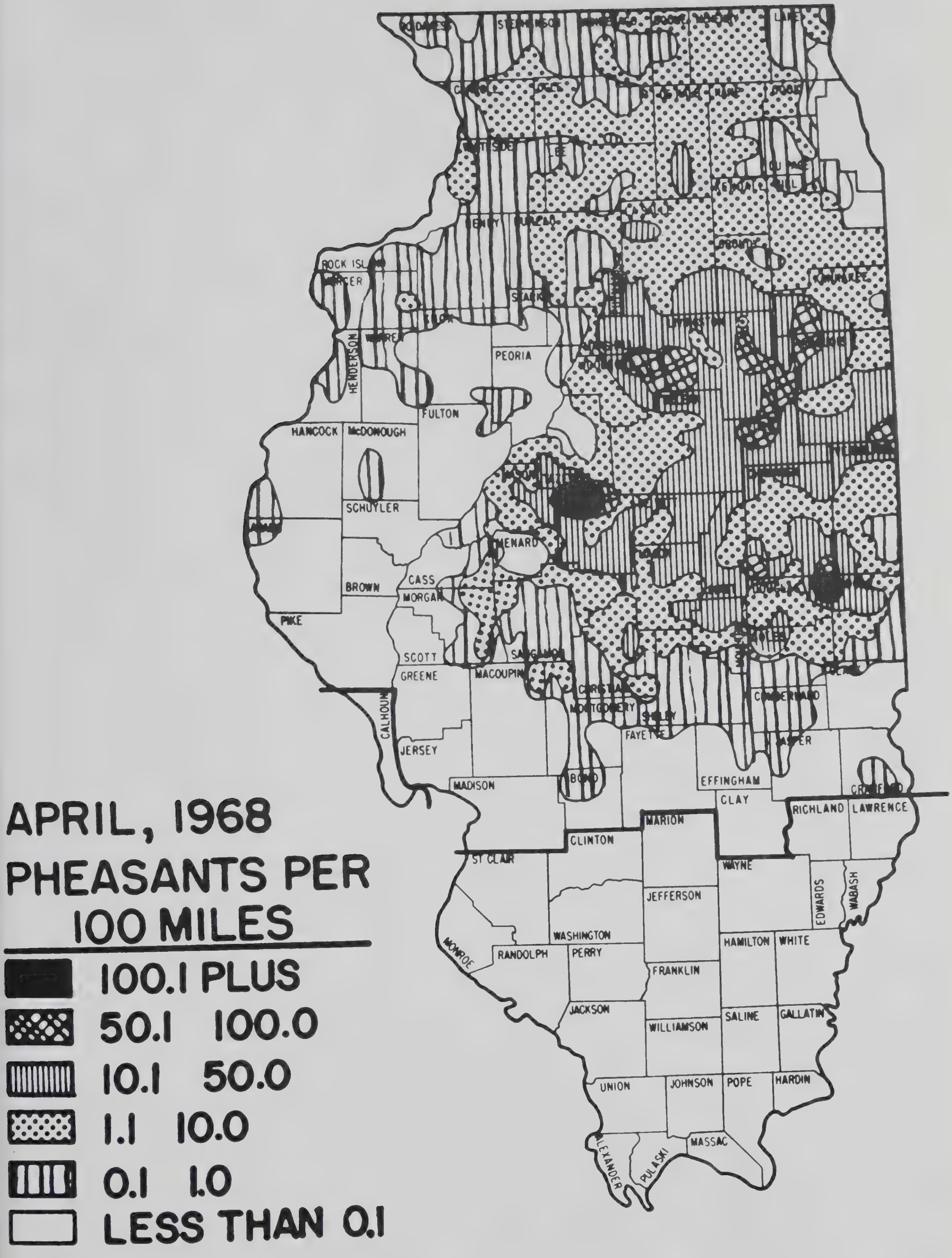

Fig. 10.—Distribution and abundance of pheasants in Illinois obtained by a rural mail carrier census (after Labisky 1969). Counties below heavy line were not censused.

Table 3.—Comparative abundance of pheasants as reported by rural mail carriers in the 74 northernmost counties of Illinois in April 1958, 1963, 1968, 1973, and 1978 (data from 1958-1973 after Labisky 1975).

	PHEASANTS PER 100 MILES					COUNTY RANK		PERCENT CHANGE	
COUNTY	1958	1963	1968	1973	1978	1973	1978	1968 to 1973	1973 to 1978
MASON	2.7	5.4	6.4	10.1	6.3	12	1	+ 58	– 38
WINNEBAGO	1.5	0.6	1.0	3.9	2.4	25	2	+290	– 38
CARROLL	1.9	1.1	2.0	5.4	2.4	20	3	+170	– 55
LEE	6.2	3.1	2.8	4.9	2.2	21	4	+ 75	– 56
STEPHENSON	5.4	0.3	0.9	2.2	2.1	37	5	+144	– 5
KENDALL	7.4	4.8	5.0	7.4	2.1	18	6	+ 48	– 72
WOODFORD	15.6	21.8	21.4	9.2	2.0	13	7	– 57	– 78
DE KALB	10.4	5.2	8.0	4.1	1.9	24	8	– 49	– 54
WILL	4.6	3.0	2.7	2.5	1.9	34	9	– 7	– 25
OGLE	1.5	0.5	2.0	3.0	1.8	28	10	+ 50	– 41
MCHENRY	7.0	3.9	3.4	2.5	1.6	32	11	– 26	– 37
LIVINGSTON	56.4	99.1	33.3	25.2	1.5	2	12	– 24	– 94
BOONE	5.1	1.0	2.3	3.1	1.4	27	13	+ 35	– 55
LOGAN	8.3	9.7	31.1	20.7	1.4	3	14	– 33	– 93
FORD	50.7	75.8	29.2	30.2	1.3	1	15	+ 3	– 96
MACON	0.7	6.6	8.5	12.0	1.3	9	16	+ 41	– 89
WHITESIDE	0.3	0.3	0.8	2.5	1.2	33	17	+213	– 52
KANE	3.6	2.7	1.7	2.8	1.2	31	18	+ 65	– 57
TAZEWELL	6.1	8.5	6.5	4.4	1.2	22	19	– 32	– 73
LA SALLE	12.4	13.8	9.1	7.5	1.2	17	20	– 18	– 84
MCLEAN	27.7	43.1	17.0	12.0	1.1	8	21	– 29	– 91
BUREAU	1.3	0.5	1.0	1.7	1.1	40	22	+ 70	– 35
SHELBY	0.2	0.5	0.7	2.3	1.1	36	23	+229	– 52
CHRISTIAN	0.2	1.2	3.5	5.8	1.1	19	24	+ 66	– 81
IROQUOIS	28.9	43.4	15.7	17.8	1.1	4	25	+ 13	– 94
MENARD	0.6	1.0	2.3	3.0	1.0	29	26	+ 30	– 67
LAKE	2.0	1.2	1.1	1.1	0.9	44	27	0	– 18
GRUNDY	12.5	17.7	9.3	8.3	0.8	16	28	– 11	– 90
MOULTRIE	1.4	11.3	18.1	15.9	0.8	5	29	– 12	– 95
DE WITT	6.5	16.1	12.2	14.9	0.8	6	30	+ 22	– 95
DU PAGE	4.9	4.3	1.2	1.8	0.7	39	31	+ 50	– 61
HENRY	1.8	0.3	0.3	0.7	0.7	46	32	+133	0
KANKAKEE	15.3	19.7	10.1	8.4	0.6	15	33	– 17	– 93
VERMILION	17.3	11.1	9.8	10.9	0.6	11	34	+ 11	– 95
PUTNAM	10.8	19.1	10.6	2.9	0.5	30	35	– 73	– 83
STARK	4.2	0.5	0.2	0.5	0.5	47	36	+150	0
EDGAR	5.0	4.2	5.3	4.1	0.5	23	37	– 23	– 88
MARSHALL	14.6	15.0	8.2	3.3	0.5	26	38	– 60	– 85
CHAMPAIGN	25.7	35.6	16.8	13.3	0.4	7	39	– 21	– 97
MERCER	0.1	0.5	0.4	0.3	0.4	50	40	– 25	+ 33
COOK	2.8	1.6	1.4	2.2	0.4	38	41	+ 57	– 82
PIATT	11.8	34.6	17.7	11.9	0.4	10	42	– 33	– 97
DOUGLAS	8.7	14.3	8.6	8.6	0.4	14	43	0	– 95
SANGAMON	0.3	0.6	1.5	1.3	0.4	42	44	– 13	– 69
COLES	2.0	2.3	3.2	2.5	0.4	35	45	– 22	– 84
JO DAVIESS	1.2	0.3	0.2	1.2	0.4	43	46	+500	– 67
CUMBERLAND	0.3	0.1	0.1	0.0+	0.2	61	47	. . .	. . .
CASS	0.2	0.8	1.2	0.8	0.2	45	48	– 33	– 75
MCDONOUGH	0.6	0.0+	0.0+	0.0+	0.2	63	49	0	. . .
HENDERSON	0.5	0.0	0.0+	0.2	0.2	57	50	0	0
WARREN	0.3	0.1	0.0+	0.1	0.2	54	51	+	+100
MONTGOMERY	0.1	0.1	0.3	0.3	0.2	49	52	0	– 33
ROCK ISLAND	0.1	0.1	0.1	0.2	0.1	51	53	+ 50	– 50
FAYETTE	0.1	0.0	0.0+	0.0	0.1	. . .	54	. . .	+
FULTON	0.0+	0.0	0.1	0.0+	0.1	58	55	–	. . .
MACOUPIN	0.0	0.0+	0.1	0.1	0.1	53	56	0	0
HANCOCK	0.0	0.0	0.0+	0.0+	0.1	59	57	0	. . .
KNOX	0.0+	0.1	0.1	0.1	0.1	56	58	0	0
EFFINGHAM	0.8	0.1	0.0+	0.1	0.1	55	59	+	0

Table 3.—Continued.

JASPER	1.0	0.1	0.0+	0.0+	0.1	62	60	0	+
CLARK	0.1	0.1	0.0+	0.4	< 0.1	48	61	+	– 90
PEORIA	0.4	0.1	0.1	0.0+	< 0.1	60	62	–	– 90
JERSEY	0.0	0.0+	0.0	0.0	< 0.1	. . .	63	0	+
CRAWFORD	0.0	0.0	0.0+	0.0	< 0.1	. . .	64	+	+
GREENE	0.1	0.1	0.0	0.0	< 0.1	. . .	65	+	+
BOND	0.0	0.0	0.0+	0.0	< 0.1	. . .	66	–	+
MORGAN	0.1	0.2	0.4	1.6	< 0.1	41	67	+300	– 99
SCHUYLER	0.0	0.0	0.0	0.1	0.0	57	. . .	+	–
CLAY	0.3	0.0	0.0	0.0	0.0	. . .	. . .	0	0
BROWN	0.0	0.0	0.0	0.0	0.0	. . .	. . .	0	0
SCOTT	0.0	0.0	0.0	0.0	0.0	. . .	. . .	0	0

+ denotes nominal increase

- denotes nominal decrease

0.0 + (prior to 1973) and 0.1 (1973-1978) mean the same thing.

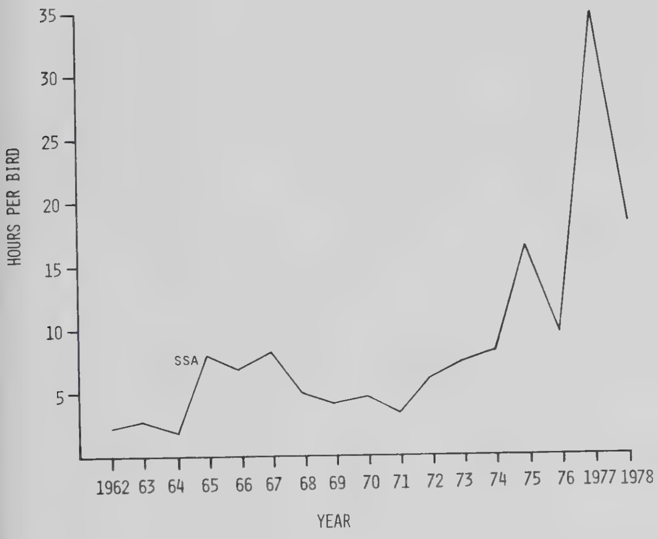

Fig. 11.—Hunter hours expended per cock pheasant bagged during the opening weekend on the Sibley Study Area, 1962-1978.

townships had no recorded sightings during the past five RMCC's.

The east-central counties, Livingston, Ford, McLean, Iroquois, and Champaign, which ranked highest in densities of pheasants for at least 3 decades (Table 3, Labisky 1975), ranked 12, 15, 21, 25, and 39, respectively, in 1978. Population trends on the SSA (Fig. 3) substantiate these dramatic declines. The west/southwestern counties, which evidenced substantial increases in the late 1960's and early 1970's (Labisky 1957:7), generally ranked lower in 1978 (Table 3) except Mason County, which had the greatest abundance of pheasants in the state in 1978 (Table 3, Fig. 14).

Pheasant Harvest.—The estimated hunter kill of cock pheasants averaged 810,000 birds annually, 1970-1974, and 522,000 birds, 1975-1978 (Table 1). This decline is also noted in the recent RMCC.

Land Use.—The amount of farmland planted in nonrow-crop cover continued to decline in the 1970's. Declines were extensive in the east and central regions and minimal in west, west/southwest, and east/southeast sectors (Fig. 15). Areas of the pheasant range least intensively farmed presently have about 25 percent of farmland in nonrow crops; the most intensively cultivated east-central cash grain regions have 10 percent or less farmland in nonrow crops (Fig. 8).

There was a modest increase in hay and small grain acreages in Illinois from 1974 to 1976 (Fig. 7). Nearly all of this increase reflected expanded production of wheat—a 33-percent increase (Illinois Cooperative Crop Reporting Service 1975, 1977).

Winter Mortality

The vast (84 percent) decline in the abundance of pheasants indicated by the 1973 and 1978 RMCC's (Table 2) reflects more than continued expansion of corn and soybean production and related losses of nest and brood cover. The winters of 1976-1977 and 1977-1978 were of unprecedented severity for ring-neck populations in Illinois. Illinois winters are generally mild, and Robertson (1958:21) concluded, "Pheasants in east-central Illinois . . . thus appeared to be far more tolerant of the near-absence of heavy winter cover than was the case in other Midwestern areas." However, the heavy snowfall, below-zero temperatures, and winds in excess of 69 km per hour over much of the state in January 1977, caused wide spread mortality of pheasants (Warner & David 1978). Biologists reported mortality in 20 counties after the storm; from one-half to two-thirds of the pheasants on five areas of investigation in east-central counties succumbed to exposure (Fig. 16) (Warner & David 1978).

The mortality rate of pheasant populations in the winter storms of 1977-1978 approached, that of the preceding winter in east-central Illinois (Warner 1978:6). The combined effects of two consecutive decimating winters no doubt account for much of the decline noted by the 1978 RMCC (Fig. 13).

Frozen specimens collected in 1977 and 1978 indicated mortality related to exposure; most exposure-killed birds were found with substantial body fat reserves and food in their crops (Warner & David 1978:117). The fact that pheasants typically roost in open fields makes them

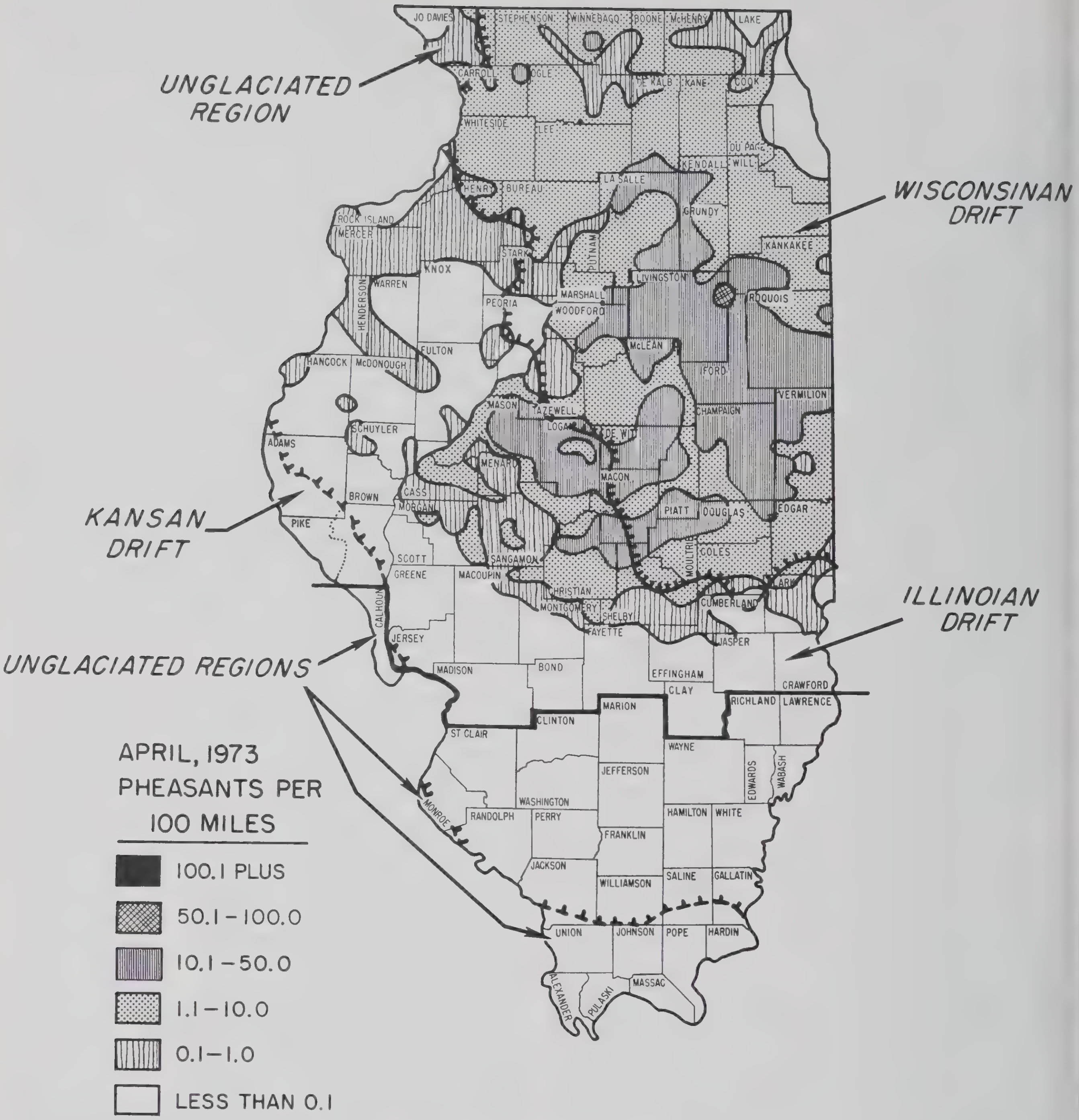

Fig. 12.—Distribution and abundance of pheasants in Illinois obtained by a rural mail carrier census, April 1973 (after Labisky 1975). Counties below the heavy line were not censused.

particularly susceptable to severe storms during the night and early morning hours, such as occurred in 1977 and 1978.

On pheasant study areas in east-central Illinois declines in pheasant populations from 1976 to 1978—the period encompassing severe winter storms—were greatest where densities of pheasants were highest, regardless of differences in the amount of protective woody cover present (R. E. Warner and L. M. David, unpublished data).

This phenomenon may have occurred throughout most of Illinois' pheasant range. Assuming the 1973 RMCC provides an index of pheasant abundance prior to winter storm-induced mortality, a regression test of pheasants observed per 100 miles in 1973 (by county) on pheasants observed per 100 miles in 1978 (Table 3) indicates that 37 percent of the variation in magnitude of declines by county is explained by population density (r = 0.607, F_{1}, 72 = 42.003; $P < 0.001$). Although winter weather and land use varied from one region to another, mortality was highest where densities of pheasants were greatest.

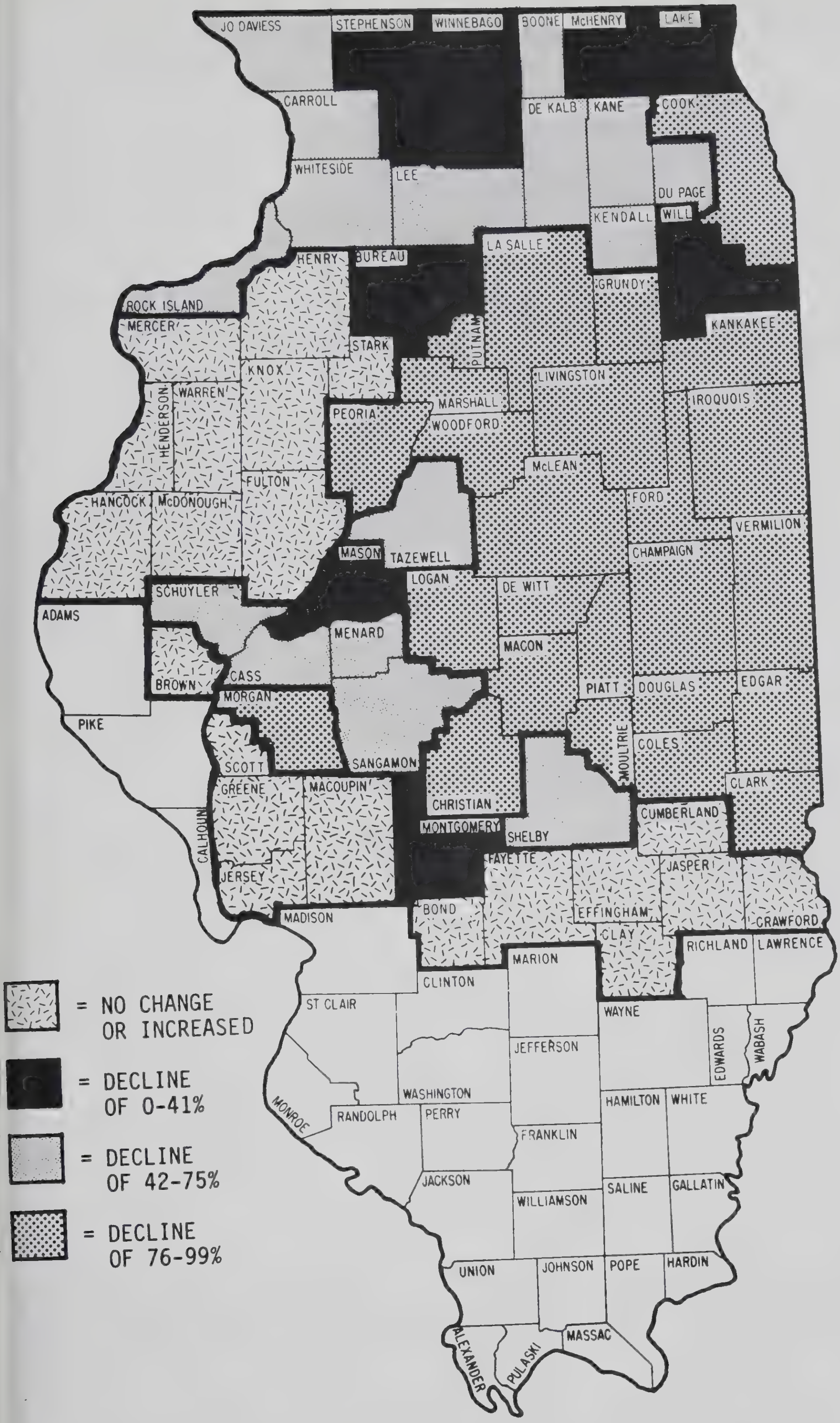

Fig. 13.—Magnitude of change in pheasants observed per 100 miles by driving during rural mail carrier censuses conducted April 1973 and April 1978.

DISCUSSION

Government Programs for Wildlife Habitat

In recent years, agriculture in Illinois, as in the United States in general, has been plagued by chronic overproduction leading to insufficient markets and unstable prices for farm commodities (Spitze 1972).

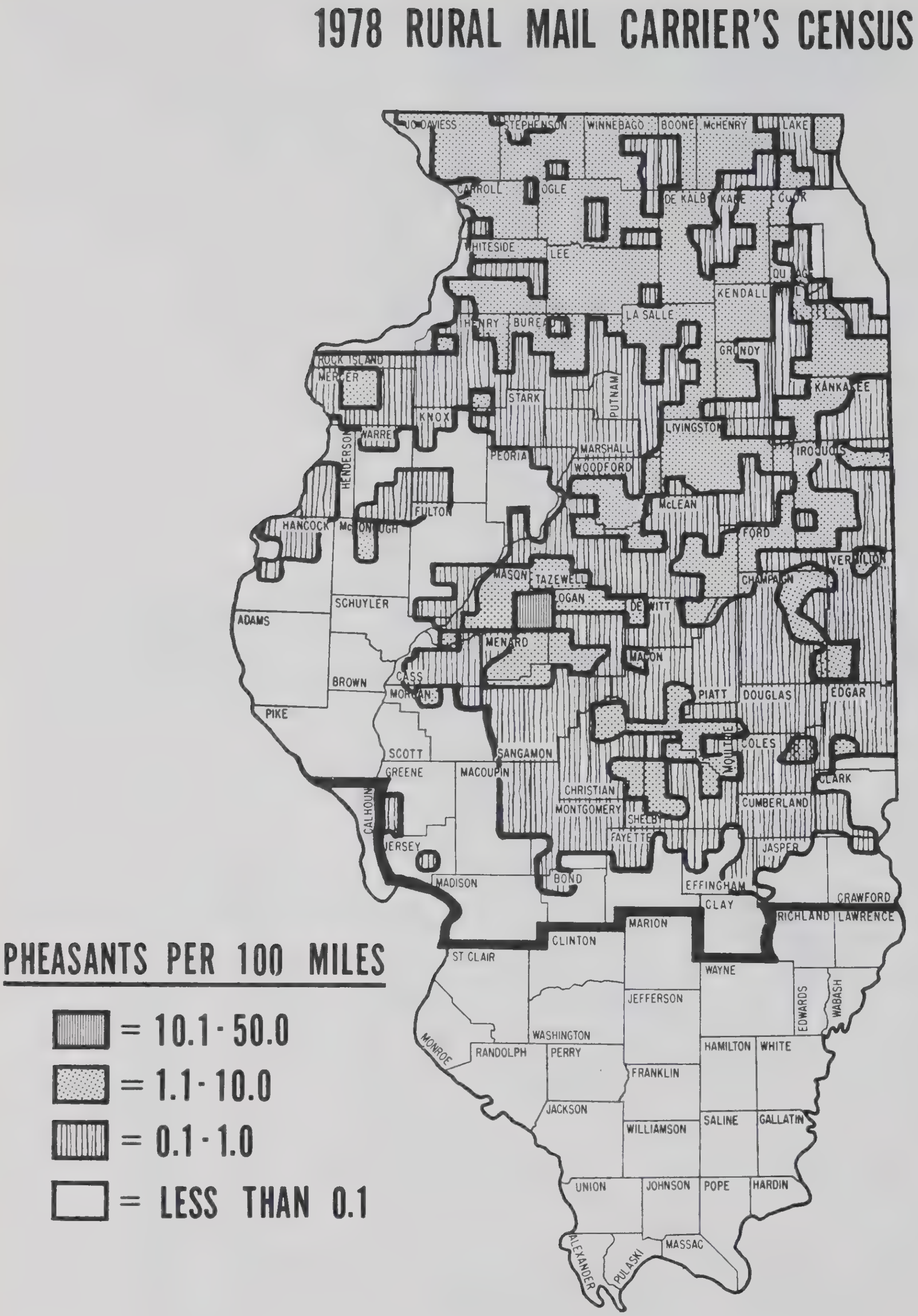

Fig. 14.—Distribution and abundance of pheasants in Illinois obtained by a rural mail carrier census, April 1978. Counties below the heavy line were not censused.

Expanded corn and soybean production has created extensive soil loss through erosion in some areas (Held & Clawson 1965, Tinus 1976). Moderation of these trends, whether government-invoked or voluntary, could improve pheasant habitat. It is doubtful however, that such moderations will result in long-term benefits to pheasants without interagency cooperation. For example, programs aimed at reducing production of feed grains or at establishing soil-building or soil-protecting vegetation could provide pheasants with undisturbed cover for nesting. The Set-Aside Acres Program of the early 1960's was one of the few such endeavors that have resulted in substantial benefits to ground nesting birds in the Midwest (Joselyn & Warnock 1964; Harmon & Nelson 1973).

The DOC offers technical and cost-sharing programs through regional offices to assist the landowner in establishing wildlife habitat. "Roadsides for Wildlife," a program initiated in 1972, is designed to establish safe nest habitat along rural road rights-of-way in east-central

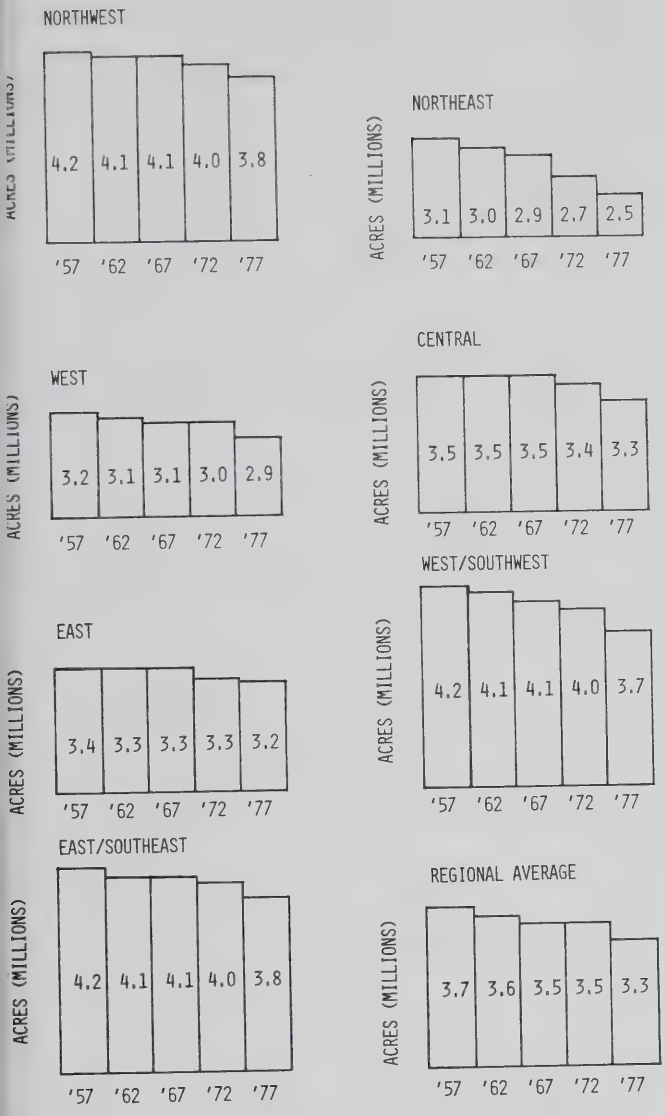

Fig. 15.—Farmland acres by region in the Illinois pheasant range, 1957-1977 (Data from Illinois Cooperative Crop Reporting Service 1968, 1978).

Illinois. In a cooperative agreement, the DOC seeds brome-alfalfa along roadsides, and farm operators annually delay mowing until 1 August. Developed roadside vegetation has been an important supplement to other nest habitat on experimental areas in east-central Illinois (Joselyn et al. 1968, Warner & Joselyn 1978).

Habitat

"The association with agriculture is so intimate that pheasant study in Illinois becomes chiefly a study of the effects of farming practices and crop phenologies upon the life activities of the bird," (Robertson 1958:13). Research has shown that populations of pheasants thrive where fields of hay (prime nest cover) and oats-hay (brood feeding areas) are common (Joselyn et al. 1968, Warner 1979). Range-wide trends in pheasant abundance and land use substantiate these findings. The era of the late 1940's and early 1950's was characterized by peak hay-oats acreages in Illinois (Fig. 7), and perhaps the greatest numbers of pheasants. Farm policies of the early 1960's halted the expansion of corn production in east-central Illinois (Fig. 2, 7) and encouraged planting of hay and oats—much of which was not harvested or clipped until post-nesting season (Joselyn & Warnock 1964). The prime habitat fostered by this farm policy supported high densities of pheasants in the east-central range that are still remembered.

Evaluations of habitat for reproduction for pheasants in Illinois cannot be simplified to merely the amount of nonrow-crop cover. In South Dakota the actual acreages devoted to nonrow crops have not been as significant to pheasant populations as the quality of grassy cover and lack of disturbance (Dahlgren 1967, Harmon & Nelson 1973).

In the mid-1970's nonrow-crop plantings increased moderately in Illinois (Fig. 7); yet no corresponding increase in numbers of pheasants was detected in the 1973 census (Fig. 17). These expanded acreages of wheat (Illinois Cooperative Reporting Service 1976) failed to provide attractive ground cover during the nest establishment period (Warner 1978:8). Furthermore, the relatively few late-nesting hens in wheat are typically disturbed by mid-summer combining operations.

Farmland Loss

The loss of farmland to urban expansion has been extensive for the northeastern sector of the state—

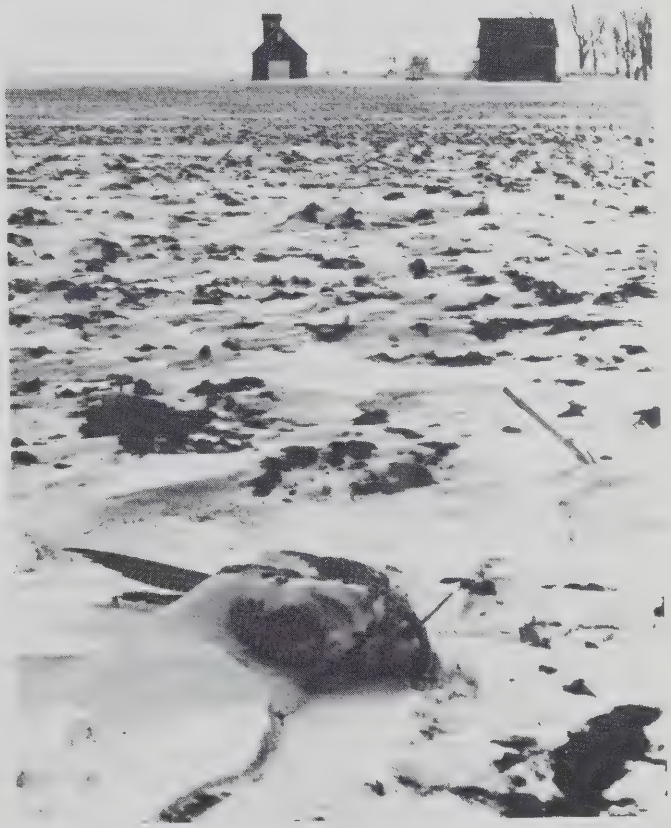

Fig. 16.—A hen pheasant found frozen in a field in Ford County following the January 1977 storm.

particularly in the decade of the 1970's. The present rate of urban sprawl is alarming in these counties, which once sustained the greatest density of pheasants in the state.

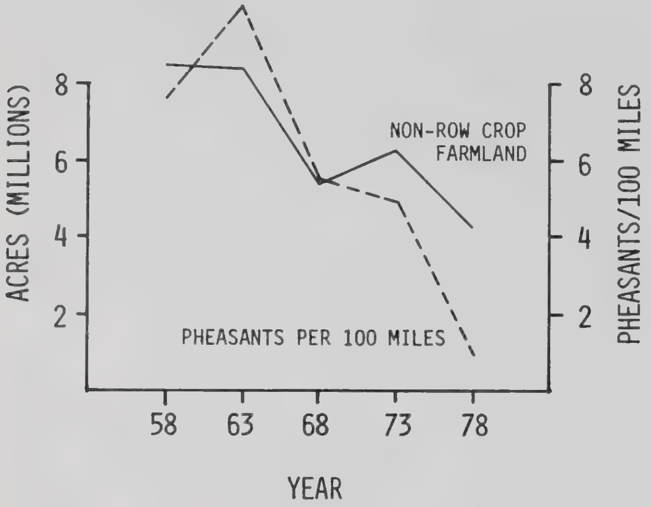

Fig. 17.—Pheasants observed per 100 miles of driving during April rural mail carrier censuses compared with nonrow crop farmland acreages, 1958-1978.

However, in the short run these changes are not entirely detrimental to ring-necks. Fields sited for development in suburban areas sometimes remain undisturbed for several years. Vegetation comprising early old field succession offers prime habitat for pheasants year round. In addition, the purchase of small (1-49 acres) tracts of land by "hobby farmers" has become a significant trend in the last decade in counties adjoining metropolitan areas (J. C. van Es, University of Illinois, Department of Agricultural Economics, personal communication). These landowners are not prone to farm intensively for income.

SUMMARY

With the exception of counties in the peripheral pheasant range, recent declines in populations have been range wide. Northern and west/southwest counties showed smaller declines from 1973 to 1978 than the east-central counties, the former prime range. Greater population densities in northern and west/southwest counties (compared with that of the east-central area) were attributed to: 1) relatively more protective (primarily herbaceous) overwintering cover, and 2) more hay and small grain fields. Most of these counties had exhibited moderate gains in numbers of pheasants in 1968 and 1973 (Table 3). Winter storm-related mortality masked any further relative increases in pheasant densities in these areas. There is also evidence that pheasants in western counties peripheral to the main pheasant range may be gradually increasing in numbers (Table 3) and area of range occupation (Fig. 6 and 15).

The annual harvest of pheasants by hunters in the next several years will probably not exceed 400,000 to 500,000 cocks—similar to the average kill noted for 1975-1978 (Table 1). Sport hunting of pheasants can be enjoyed in the future without reductions in bag limit or season length; pheasant hunting in the Prairie State has not impinged on the reproductive capabilities of the ring-neck.

Future management of pheasant populations in Illinois should be directed toward establishment of habitat for nesting and brood foraging. Winter roost cover is generally of secondary importance. To substantially increase numbers of pheasants, habitat on agricultural lands would have to be improved.

CONCLUSIONS

The highly fertile east-central cash grain belt has in past years demonstrated the greatest potential for sustaining large numbers of pheasants. The cash grain region and other sectors of the range (especially northern counties) may show increases in numbers of pheasants over the next few years, perhaps approaching pre-winter storm densities of pheasants; however, dramatic increases cannot be anticipated under current land use constraints. Unless extensive corn and soybean production with associated clean farming practices are moderated, "boom" populations of pheasants in Illinois will remain only a memory.

REFERENCES CITED

Allen, D. L. 1947. Hunting as a limitation to Michigan pheasant populations. Journal of Wildlife Management 11:232-243.

______ . 1953. Pheasants afield. Stackpole Co., Harrisburg, Pennsylvania. 128 p.

______. 1943. Our wildlife legacy. Funk and Wagnalls Co., New York. 422 p.

Anderson, W. L. 1964. Survival and reproduction of pheasants released in southern Illinois. Journal of Wildlife Management 28:254-264.

______. 1968. Experimental releases of pheasants in Wabash County, Illinois. Illinois State Academy of Science Transactions 61:367-375.

______, and P. L. Stewart. 1969. Relationships between inorganic ions and the distribution of pheasants in Illinois. Journal of Wildlife Management 33:254-270.

Bennett, L. J. 1945. The pheasant in Pennsylvania and New Jersey, Pages 11-31 *in* W. L. McAtee, ed, the ring-necked pheasant and its management in North America. American Wildlife Institute, Washington, D.C.

Besadny, C. D., and F. H. Wagner. 1963. An evaluation of pheasant stocking through the day-old-chick program in Wisconsin. Wisconsin Conservation Department Technical Bulletin 28. 84 p.

Brady, S. J. 1974. Experimental releases of ring-necked pheasants *(Phasianus colshicus L.)* in McDonough County, Illinois. M. S. Thesis. Western Illinois University. 96 p.

Dahlgren, R. 1967. What happened to our pheasants in 1966? South Dakota Conservation Digest 34(4):6-9.

Ekblaw, E. L., and S. E. Ekblaw. 1926. Paxton, Illinois (Christmas bird census). Bird-Lore 28:44.

Ellis, J. A., and W. L. Anderson. 1963. Attempts to establish pheasants in southern Illinois. Journal of Wildlife Management 27:225-239.

______, Ellis, J. A. 1978. Estimating game and fur harvest: Hunter mail survey, 1977-78. Illinois Department of Conservation Job Completion Report. 30 p.

Errington, P. A. and F. N. Hamerstrom, Jr. 1937. The evaluation of nesting losses and juvenile mortality of the ring-necked pheasant. Journal of Wildlife Management. 1:3-20.

Errington, P. L. 1945. The pheasant in the northern prairie states. Pages 190-202 *in* W. L. McAtee, ed. The ring-necked pheasant and its management in North America. American Wildlife Institute, Washington, D.C.

Etter, S. L. 1966. Characteristics of pheasant populations under intensive farming. Job Completion Report. Illinois Cooperative Wildlife Research W-66-R-6. 11p.

Fehrenbacher, J. B., G. O. Walker, and H. L. Wascher. 1967. Soils of Illinois. University of Illinois College of Agriculture Agricultural Experiment Station Bulletin 725. 47 p.

Forbes, S. A., and A. O. Gross. 1923. On the numbers and local distribution of Illinois land birds of the open country in winter, spring and fall. Illinois Natural History Survey Bulletin 14(10):397-453.

Greeley, F., R. F. Labisky, and S. H. Mann, 1962. Distribution and abundance of pheasants in Illinois. Illinois Natural History Survey Biological Notes 47. 16 p.

Harmon, K. W., and M. M. Nelson. 1973. Wildlife and soil considerations in land retirement programs. Wildlife Society Bulletin 1:28-38.

Held, R. B., and M. Clawson. 1965. Soil conservation in perspective. Johns Hopkins Press, Baltimore. 344 p.

Illinois Cooperative Crop Rrporting Service. 1968. Illinois agricultural statistics: field crops by counties twenty-one years 1945-1965. 155 p.

______ . 1975. Illinois Agricultural statistics: assessors' annual farm census, 1974. 27 p.

______ . 1976. Illinois agricultural statistics: assessors' annual farm census, 1975. 28 p.

______ . 1977. Illinois agricultural statistics: assessors' annual farm census, 1976. 28 p.

______ . 1978. Illinois agricultural statistics: assessors' annual farm census, 1977. 28 p.

Jones, R. L., R. F. Labisky, and W. L. Anderson. 1968. Selected minerals in soils, plants, and pheasants: An ecosystem approach to understanding pheasant distribution in Illinois. Illinois Natural History Survey Biological Notes 63. 8 p.

Joselyn, G. B., and J. E. Warnock. 1964. Value of Federal Feed Grain Program to production of pheasants in Illinois. Journal of Wildlife Management 28:547-551.

______, J. E. Warnock, and S. L. Etter. 1968. Manipulation of roadside cover for nesting pheasants—a preliminary report. Journal of Wildlife Management 32:217-233.

Kimball, J. W. 1948. Pheasant population characteristics and trends in the Dakotas. North American Wildlife Conference Transactions 13:291-314.

Klimstra, W. D., and D. Hankla. 1953. Preliminary report on pheasant stocking in southern Illinois. Illinois State Academy of Science Transactions 46:235-239.

Labisky, R. F. 1961. Why the three-bird bag limit on cock pheasants? Illinois Wildlife 16(3):13-14.

______ . 1968. Ecology of pheasant populations in Illinois. Ph.D. Thesis. University of Wisconsin, Madison. 511 p.

______. 1969. Trends in pheasant abundance in Illinois: 1958 to 1968. Illinois Natural History Survey Biological Notes 65. 8 p.

______ . 1975. Illinois pheasants: Their distribution and abundance, 1958-1973. Illinois Natural History Survey Biological Notes 94. 11 p.

______ , J. A. Harper, and F. Greeley. 1964. Influence of land use, calcium, and weather on the distribution and abundance of pheasants in Illinois. Illinois Natural History Survey Biological Notes 51. 19 p.

______ , and W. L. Anderson. 1965. Changes in distribution and abundance of pheasants in Illinois: 1958 versus 1963. Illinois State Academy of Science Transactions 58:127-135.

Leedy, D. L., and L. E. Hicks. 1945. The pheasants in Ohio. Pages 57-130 *in* W. L. McAtee, ed., the ring-necked pheasant and its management in North America. American Wildlife Institute, Washington D.C.

Leopold, A. 1931. Report on a game survey of the North Central States. Sporting Arms and Ammunition Manufacturers' Institute. Madison, Wisconsin. 299 p.

Marquardt, W. C., and T. G. Scott. 1952. It's in the bag. Illinois Wildlife 7(2):4-5.

McAtee, W. L. 1929. Game birds suitable for naturalizing in the United States. U.S. Department of Agriculture Circular 96. 24 p.

______ , ed. 1945. The ring-necked pheasant and its management in North America. American Wildlife Institute, Washington D.C. 320 p.

McCabe, R. A., R. A. MacMullan, and E. H. Dustman. 1956. Ringneck pheasants in the Great Lakes region. Pages 264-356 *in* D. L. Allen, ed., Pheasants in North America. Stackpole Co., Harrisburg, Pennsylvania and Wildlife Management Institute, Washington D.C.

Odum, E. P. 1971. Fundamentals of ecology, 3rd ed. W. B. Saunders Company, Philadelphia. 574 p.

Osborne, L. B. 1943. Meet Mr. Ringneck. Illinois Conservation 8(4):12.

Phillips, J. C. 1928. Wild birds introduced or transplanted in North America. Department of Agriculture Technical Bulletin 61. 63 p.

Preno, W. L., and R. F. Labisky. 1971. Abundance and harvest of doves, pheasants, bobwhites, squirrels, and cottontails in Illinois, 1956-69. Illinois Department of Conservation Technical Bulletin 4. 76 p.

Robertson, W. B., Jr. 1958. Investigations of ring-necked pheasants in Illinois. Illinois Department of Conservation Technical Bulletin 1. 137 p.

Ross, R. C., and H. C. M. Case. 1956. Types of farming in Illinois: an analysis of differences by areas. University of Illinois Agricultural Experiment Station Bulletin 601. 88 p.

Schlebecker, J. T. 1975. Whereby we thrive: A history of American farming, 1607-1972. Iowa State University Press, Ames. 342 p.

Schwartz, L. 1950. Game Propagation Division. Pages 18-23 *in* Illinois Department of Conservation annual report.

Selye, H. 1949. The general-adaption-syncrome and the diseases of adaptation. Pages 837-867 *in* H. Selye, Textbook of endocrinology. Acta Endocinologica, University of Montreal, Canada. 914 p.

Spitze, R. G. F. 1972. Policy direction and economic interpretations of the U.S. Agricultural Act of 1970. Journal of Agricultural Economics 23(2):99-108.

Tinus, R. W., ed., 1976. Shelterbelts on the great plains: Proceedings of the symposium. Great Plains Agricultural Council Publication 78. 218 p.

Vestal, A. G. 1931. A preliminary vegetation map of Illinois. Illinois State Academy of Science Transactions 23:204-217.

Vinzant, L. J. 1978. Evaluation of ring-necked pheasant *(Phasianus colchicus)* releases in McDonough and Hancock counties, Illinois. M.S. Thesis. Western Illinois University. 98 p.

Wagner, F. H., C. D. Besadny, and C. Kabat. 1965. Population ecology and management of Wisconsin pheasants. Wisconsin Conservation Department Technical Bulletin 34. 168 p.

Walcott, F. C. 1945. Historical introduction. Pages 1-5 *in* W. L. McAtee, ed., the ring-necked pheasant and its management in North America. American Wildlife Institute, Washington D.C.

Warner, R. E. 1975. Cover utilization by pheasant broods in east-central Illinois, 1972-1973. M.S. Thesis. University of Illinois. 39 p.

______ . 1978. Illinois pheasant studies. Job Completion Report. Illinois Cooperative Wildlife Research W-66-R-18. 29 p.

______ , and L. M. David. 1978. Winter storm-related mortaility of pheasants in Illinois, 1977. Illinois State Academy of Science Transactions 71(1):115-119.

______, and G. B. Joselyn. 1978. Roadside management for pheasants in Illinois: Acceptance by farm cooperators. Wildlife Society Bulletin 6:128-134.

______. 1979. Use of cover by pheasant broods in east-central Illinois. Journal of Wildlife Management 43:334-346.

Yeager, L. E. 1947. Big city chinks. Illinois Conservation 12(1):8-9, 15.

Yeatter, R. E. 1943. Weather, cycles and upland game populations. Illinois Conservation 9(3):8,9.

______, and L. E. Yeager. 1945. Upland game birds: how do you rate them? Illinois Conservation 10(1):6, 36.

______. 1953 Air temperature affects pheasant range. Illinois Wildlife 9(1):5-6.

______. 1957. Is the prairie chicken doomed? Illinois Wildlife 12(2):7-8.

A familiar scene during pheasant season in Illinois.

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EFFECTS OF INGESTED LEAD-IRON SHOT ON MALLARDS

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Effects of Ingested Lead-Iron Shot on Mallards

Glen C. Sanderson
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Sarah S. Hurley

ABSTRACT

Each of nine wild male mallards in each of 12 groups was dosed as follows: 0 shot (control group); 1 No. 4 lead shot; 5 No. 4 steel shot; 1, 3, or 5 No. 4 shot of 36.67 percent lead and 63.33 percent iron; 1, 3, or 5 No. 4 shot of 60.90 percent lead and 39.10 percent iron; or 1, 3, or 5 shot of 64.60 percent lead and 35.40 percent iron.

In an average of 28.5 days, 2.1 percent of the shot was expelled. The weight of shot eroded varied from 21 to 62 percent. The weight eroded per shot per day varied from 1.0 to 2.0 percent. The daily rate of erosion was not significantly affected by the number of pellets in the gizzard and was significantly higher for heavy shot than for light shot.

Ducks in the control group and those dosed with steel pellets had the lowest daily losses of body weight, and the group dosed with one lead pellet each had the highest daily weight loss. Mean weights of surviving ducks on 28 May and 12 June showed significant inverse relationships with the weight of lead dosed. Apparently, ducks given only one lead-iron shot with up to 65 percent lead and ducks given as many as five lead-iron shot with up to 37 percent lead receive substantial protection from lead poisoning by some action of the iron. Although there is evidence that the iron gave some protection in all cases in the present experiment, ducks dosed with three or more lead-iron pellets containing ≥61 percent lead had significant weight losses.

Packed-cell volume (PCV) and hemoglobin (Hb) determinations support the indications of weight losses regarding effects of lead and iron. Mortality rate, body weight, and PCV are perhaps the most useful measurements for studying lead toxicity in wild captive mallards on a diet of corn. These parameters indicate not only that iron offers a protective value against lead toxicity, but also that the effects of lead are detectable at these doses even in the presence of iron.

A significant negative correlation was found between the amount of lead administered and the weight of the spleen, pancreas, liver, and kidneys. A significant positive linear relationship occurred between the amount of lead administered and the mean weight of adrenals. Active spermatogenesis was seen only in the testes of ducks in the control group and of ducks dosed with steel shot. A granular pigment appeared in both the red and white pulp of the spleens of ducks dosed with steel pellets, and it appeared in moderate amounts throughout the spleens of all ducks dosed with lead. Liver sections of all ducks, including the controls, were abnormal. Abnormal changes occurred in the liver, spleen, kidneys, and testes with all levels of lead dosage, but the changes were greater for higher lead doses. Hemosiderosis was found in the spleens and livers of all dosed ducks. Intranuclear inclusion bodies were found in kidney tubule cells of most ducks dosed with lead.

The ingestion of five steel pellets may benefit ducks, and the ingestion of up to five lead-iron pellets with up to 37 percent lead is relatively nontoxic.

INTRODUCTION

The poisoning of wild waterfowl by ingested lead shot is a continuing concern (Jordan & Bellrose 1951, Bellrose 1959, Anderson 1975). The U.S. Fish and Wildlife Service (1974. Use of steel shot for hunting waterfowl in the United States. Department of the Interior DES 74-76. 79 p. + 6 appendices.) proposed the gradual elimination of lead shot for hunting migratory waterfowl in some flyways and in certain areas in other flyways, beginning with the fall hunting season in 1976. Although the proposed regulations prohibited the taking of migratory game birds "With a shotgun containing shells loaded with shot composed of any metal other than such material as may be determined by the Director to be nontoxic to migratory waterfowl. . . ." (U.S. Fish and Wildlife Service. 1974. Use of steel shot for hunting waterfowl in the United States. Department of the Interior DES 74-76. 79 p. + 6 appendices.), the preliminary impact statement implied (1974:75) that only soft steel shot and a mixture of lead and iron shot appeared promising as a substitute for lead shot for hunting migratory waterfowl.

Because of reduced toxicity with ingested lead-iron shot in captive waterfowl as reported by Irwin et al. (1974), Dr. Edward L. Kozicky, Director of Conservation, Winchester Group, Olin Corporation, asked the Illinois Natural History Survey to conduct an additional study, using lead-iron shot in captive wild waterfowl.

METHODS

Wild male mallards (*Anas platyrhynchos*) were trapped on 20 March 1974 at the Union County Refuge in southern Illinois and on the Keokuk Pool on the Mississippi River and were transported to the Illinois Natural History Survey Laboratory, Havana, Illinois. They were held in two pens that were 9.1 x 3.6 x 0.6 m (30 x 12 x 2 feet) (Jordan & Bellrose 1950:157) and were provided duck pellets, cracked corn and water ad libitum

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This paper is published by authority of the State of Illinois and is a contribution from the Section of Wildlife Research of the Illinois Natural History Survey. Dr. Glen C. Sanderson is Wildlife Specialist and Head, Section of Wildlife Research, Illinois Natural History Survey; Dr. Horace W. Norton is Professor of Statistical Design and Analysis, Department of Animal Science, University of Illinois; and Sarah S. Hurley, D.V.M., is a former Research Associate, Illinois Natural History Survey.

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until 29 April, 15 days before the experiment began. The birds were banded with individually numbered leg bands, randomly assigned to 1 of 12 groups of 10 ducks each, and placed in 12 wire-covered pens 1.2 x 1.2 x 0.8 m (4 x 4 x 2.5 feet). Each pen had running water in a 5-inch rain gutter, a resting platform covering about half of the bottom of the pen, and a board covering half of the top of the pen. Because the rain gutter carrying running water was too small for the ducks to bathe in conveniently, the ducks did not adapt to these smaller pens, and at the start of the experiment they were returned to the two large holding pens. Losses during the conditioning period necessitated reducing the number of birds in the experiment from 10 to 9 per group. At the start of the experiment on 13 May, the ducks were placed on a diet of whole corn and water ad libitum.

The doses were as follows for the ducks in each of the 12 groups: 0 shot (controls); 1 No. 4 lead shot; 5 No. 4 steel shot; 1, 3, or 5 No. 4 shot of 36.67 percent lead and 63.33 percent iron; 1, 3, or 5 shot of 60.90 percent lead and 39.10 percent iron; and 1, 3, or 5 shot of 64.60 percent lead and 35.40 percent iron. Throughout this report, dosage groups are identified by the number of pellets given, the percentage of lead in the pellet, and the percentage of iron in the pellet. Thus, 1-100-0 equals 1 shot of 100 percent lead and 0 percent iron, and 3-37-63 indicates 3 pellets with approximately 37 percent lead and 63 percent iron. The lead-iron shot were prepared by the National Research Council of Canada from a mixture of lead and iron particles. The plans were to use shot composed of 45, 60, and 70 percent lead, but analyses indicated that the above percentages of lead and iron were as close as they came to their objectives. The all-lead and all-steel shot were taken from 12-gauge shotgun shells.

Each dose of shot was weighed before being administered to a duck, and all recovered shot were weighed. When no shot was expelled from the gizzard, we obtained the actual weight lost by the pellets while they were in the gizzard. For ducks that expelled some shot, we used average weights of shot administered to and recovered from each duck. Analysis of a number of shot removed from the gizzards showed no appreciable change in the lead:iron ratio.

The shot were placed in the proventriculus of each duck by inserting a plastic tube passed through the esophagus and were followed by approximately 5 ml of water. Controls were handled in the same manner except that they received no shot.

The ducks were dosed on 13 May 1974, and the experiment ended 12 June 1974. Birds were weighed, and blood samples for packed-cell volume (PCV), hemoglobin (Hb) determinations, and lead analyses were taken on 13 May, 28 May, and 12 June. When a duck died, it was weighed and autopsied as soon as practicable. The pens were checked for dead ducks at least twice daily.

Fresh, wet weights were obtained for testes, thyroids, spleen, pancreas, liver, kidneys, and adrenals. Tissues from the heart, lungs, liver, kidneys, gonads, spleen, and femur of two ducks in each group were preserved in 10-percent buffered neutral formalin for histological study (Luna 1968). Blood samples (at the beginning, middle, and end of the experiment) and livers from the same two ducks from each group were frozen for determination of lead contents. The ducks chosen for histological study and lead analyses were the second and sixth ducks to die in each group if they were obtained soon enough after death. In groups in which no bird died, or when fewer than two or six ducks had died by the end of the experiment, the second and sixth ducks autopsied at the end of the experiment, or the last duck autopsied if fewer than six remained in the group, were chosen for histological study and lead analyses.

Except for the kidneys, which were stained with Kinyown's carbolfuchsin for acid-fast nuclear inclusion bodies, tissue sections were stained with hematoxylin and eosin. The method of preparing the bone for sectioning and staining did not permit the evaluation of bone marrow activity.

Blood smears were stained with hematoxylin and eosin. The initial sample from each duck was used as the control or base line for evaluating subsequent samples from each duck. Each smear was evaluated by cellular morphology.

White-blood-cell differential counts were performed on individual smears to try to quantitate the effects of the various shot doses. A malaria-like infection of the red blood cells prevented effective use of this datum. This infection influenced white cell differentials and caused a degree of anemia in about 30 percent of the test ducks.

The experiment was terminated on the 30th day, when all surviving ducks were weighed and blood samples were collected. All ducks selected for histological study and lead analyses were killed on the 30th day. For lack of time, the remaining ducks were killed and autopsied on the 31st day. Except for total erosion and daily rate of shot eroded in the gizzard, all determinations were made as if all ducks had been killed on the 30th day.

The ducks were decapitated and allowed to bleed freely. Blood collected for lead analyses was drawn from the wing vein, placed in 2-ml heparinized Vacutainers (TM, Becton, Dickinson and Company, Columbus, Nebraska), and frozen (5 °F). Organs collected for lead analyses were placed in individual plastic bags and frozen.

Gizzards and proventriculi were opened and searched for shot. Shot were sometimes found in the proventriculus, but the locations of shot found were not recorded. Shot recovered from each duck were placed in a coin envelope and were weighed later.

One duck escaped on 28 May as the birds were being transferred to carrying crates, and one duck expelled all five pellets administered. These two birds were eliminated from all analyses.

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RESULTS AND DISCUSSION

Percentages of Shot Expelled

Of 291 shot administered to 97 ducks, 285 shot were recovered at autopsy (Table 1). None of these ducks lost more than one shot, no treatment group lost more than two shot, and 7 of 11 groups retained all shot. As mentioned earlier, one duck expelled all five shot, presumably shortly after dosing, and was eliminated from the analysis. The total expulsion rate was 2.1 percent of the shot in an average of 28.5 days. There was no significant difference ($P > 0.05$) in the rate of shot expelled among groups.

Dosage and Rate of Erosion

Because the lead-iron shot were handcrafted, the weight of the shot varied considerably (Table 2). Thus, ducks in the 5-61-39 group were dosed with more lead and more iron than ducks in the 5-65-35 group. Five groups of ducks were given more lead than the group that was dosed with only one lead shot each.

Weight eroded varied from 21.2 percent for the 5-65-35 group to 62.0 percent for the 1-61-39 group (Table 3). The percentage of total weight of shot eroded probably relates to the mortality rate. A higher rate of exposure to lead (as in the 5-65-35 group compared with the 1-61-39 group) might result in earlier death and less total erosion of the shot.

Weight eroded per shot per day varied from 1.0 to 2.0 percent (Table 3), less than expected. The rate of erosion may be correlated with the rate of food consumption (Irwin, J. C., L. H. Karstad, and R. G. Thomson. 1974. Progress report on lead poisoning in waterfowl March 1973 to March 1974. University of Guelph, Guelph, Ontario. 66 p. Mimeographed.), and low air temperatures may encourage greater consumption of food (Jordan & Bellrose 1951:21). During the present experiment, the weather was mild, and there were indications that the rate of food consumption, although not measured, was low. The rate of erosion for one lead pellet per duck in the present experiment was 1.8 percent per day compared with 3.6 percent per day in an earlier experiment (Sanderson unpublished) in which the pens and diet were the same as in the present study, but the time was November and December, when the weather was colder and food consumption was presumably higher. Average survival time for 10 ducks in that experiment was 17.2 days, the range being 10–25 days. In the present experiment, only four of nine ducks dosed with one lead pellet each had died by 30 days after dosing, and the average time the lead pellets were in the gizzard was 26.7 days (Table 1). This finding differs from that of Jordan & Bellrose (1951:21), who reported that "the proportion of dosed birds surviving in winter was greater than that in milder seasons."

Table 1.—Numbers of shot administered and recovered, percentages of shot expelled, and average days to death of ducks.

Dose[a]	Number of Shot		Percent Expelled	Avg. Percent Expelled per Group Daily[b]	Avg. No. of Days to Death[c]
	Given	Recovered			
1-100-0	9	9	0	0.0	26.7
5-0-100	45	45	0	0.0	31.0
1-37-63	9	9	0	0.0	29.6
3-37-63	27	26	4	0.13	28.2
5-37-63[d]	40	40	0	0.0	27.6
1-61-39[e]	8	8	0	0.0	30.9
3-61-39	27	25	7	0.26	28.2
5-61-39	45	43	4	1.14	30.8
1-65-35	9	9	0	0.0	30.7
3-65-35	27	27	0	0.0	27.9
5-65-35	45	44	2	0.11	20.7
Total or mean	*291*	*285*	*2*	*0.07*	*28.5*

[a] Number of shot given-percent lead (Pb)-percent iron (Fe). Chemical analyses indicated these compositions of pellets:

37-63 = 36.67 percent Pb and 63.33 percent Fe
61-39 = 60.90 percent Pb and 39.10 percent Fe
65-35 = 64.60 percent Pb and 35.40 percent Fe

[b] As if all expelled shot were expelled on day of death.

[c] Although the experiment was terminated after 30 days, several ducks were not killed until the 31st day. These values should not be used for calculating average survival time or rate of loss of body weight.

[d] One duck expelled all five shot and was eliminated from the analyses.

[e] One duck escaped.

Cook & Trainer (1966) reported that the rate of erosion is not related to the number of shot in the gizzard. We found (Table 3) that the number of pellets had no significant ($P > 0.30$) effect on the rate of erosion per shot per day. Also, the total amount of lead administered had no significant effect ($P > 0.05$) on the percentage of each shot eroded each day, but the heavier the pellet, the higher the percentage eroded per day ($P < 0.001$). Lead percentage showed a positive but not significant ($P > 0.05$) effect on the percentage of total weight eroded each

Table 2.—Mean amounts of lead and iron administered, mean amounts eroded daily, mean daily changes in body weight, and mean daily ratios of lead and iron eroded.

Dose[a]	Mean Amount in Grams Administered			Lead Eroded in Grams per Duck		Iron Eroded in Grams per Duck		Mean Ratio of Fe: Pb Eroded Daily per Duck
	All Shot	Lead	Iron	Total	Per Day	Total	Per Day	
0-0-0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	. . .
1-100-0	0.213	0.213	0.000	0.100	0.004	0.000	0.000	0:1.00
5-0-100	0.751	0.000	0.751	0.000	0.000	0.275	0.090	1:0.00
1-37-63	0.181	0.066	0.115	0.038	0.001	0.065	0.002	1:0.58
3-37-63	0.541	0.198	0.343	0.080	0.003	0.138	0.005	1:0.58
5-37-63	0.905	0.332	0.573	0.150	0.005	0.260	0.009	1:0.58
1-61-39	0.220	0.134	0.086	0.083	0.003	0.053	0.002	1:1.56
3-61-39	0.651	0.396	0.255	0.161	0.006	0.104	0.004	1:1.56
5-61-39	1.070	0.652	0.418	0.268	0.009	0.172	0.006	1:1.56
1-65-35	0.189	0.122	0.067	0.059	0.002	0.032	0.001	1:1.82
3-65-35	0.551	0.356	0.195	0.137	0.005	0.075	0.003	1:1.82
5-65-35	0.957	0.618	0.339	0.128	0.006	0.070	0.003	1:1.82
Grand mean	*0.566*	*0.309*[b]	*0.314*[c]	*0.120*[b]	*0.004*[b]	*0.124*[c]	*0.012*[c]	*1:1.17*

[a] See Table 1, footnote a.
[b] Includes only those ducks receiving lead.
[c] Includes only those ducks receiving iron.

day (Table 3). Although we did not measure the hardness of the pellets, we had expected that pellets with a higher percentage of lead would erode faster than pellets with a higher percentage of iron. Sanderson (unpublished) found a daily rate of erosion for lead pellets (one per gizzard) of 3.62 percent compared with 0.23 percent for copper pellets (1-32 pellets per gizzard). The effect of the number of pellets on the rate of erosion was not considered in that study, but there appeared to be a slightly higher rate of erosion when more copper pellets were present.

Amount of Lead and Iron Eroded.—Because no duck in this experiment expelled more than one shot and because the time of expulsion was not determined, expelled shot are ignored in this analysis. However, every shot administered was included in calculating the dosage of lead and iron for each duck (Table 2).

In ducks dosed with shot containing lead, the average amount of lead eroded per duck varied from 0.0378 g to 0.2679 g (Table 2). As expected, there was a significant ($P < 0.001$) positive relationship between weight of lead administered and the amount eroded each day. In

Table 3.—Mean weight of shot eroded per day.

Dose[a]	Mean Weight in Grams of Each Shot Given	Mean Weight in Grams of Each Shot Recovered	Percent of Total Weight Eroded	Percent of Weight Eroded Daily per Shot
0-0-0	0.000	0.000	0	0.0
1-100-0	0.213	0.113	47	1.8
5-0-100	0.150	0.095	37	1.2
1-37-63	0.181	0.078	57	1.9
3-37-63	0.180	0.105	42	1.5
5-37-63	0.181	0.099	45	1.6
1-61-39	0.220	0.084	62	2.0
3-61-39	0.217	0.112	48	1.7
5-61-39	0.214	0.122	43	1.4
1-65-35	0.190	0.098	48	1.6
3-65-35	0.184	0.113	39	1.4
5-65-35	0.191	0.151	21	1.0
Grand mean[b]	*0.193*	*0.106*	*44*	*1.6*

[a] See Table 1, footnote a.
[b] Controls are not included.

general, the daily amount and total amount of lead eroded per duck were in relative agreement, but there were some differences (Table 2). The largest daily amount (0.0087 g) and the largest total (0.2679 g) were eroded in ducks in the 5-61-39 group. However, ducks in the 5-65-35 group eroded the second highest *daily* amount (0.0063 g), but ducks in the 3-61-39 group eroded the second highest *total* amount (0.1614 g). A higher daily erosion rate may result in an earlier death and thus in a lower total amount eroded. Ducks in the 1-100-0 group ranked sixth in both the daily amount (0.0037 g) and the total (0.0996 g) of lead eroded.

Ducks dosed with five steel shot eroded the highest daily amount (0.009 g) and the highest total amount (0.275 g) of iron per duck (Table 2). Total iron eroded ranged from 0.032 to 0.275 g per duck and from 0.001 to 0.009 g per duck per day.

Mortality Rate

Mortality rates for the 12 groups of ducks ranged from no mortality in three groups to 67 percent mortality in the 5-65-35 group (Table 4). Mild weather during the present experiment may have permitted relatively long survival, but Jordan & Bellrose (1951:21) reported that ducks dosed with lead survived better in winter than in milder seasons because of the higher intake of food in winter. As mentioned earlier, Sanderson (unpublished) found 100 percent mortality in a study conducted in November 1972.

Table 4.—Mortality and average survival time.

Dose [a]	Number of Ducks in Group	Ducks Dead Before End of Experiment		Survival in Days [b]	
		Number	Percent	Mean	Range
0-0-0	9	1	11	29	23–30
1-100-0	9	4	44	26	15–30
5-0-100	9	0	0	30	30
1-37-63	9	1	11	29	20–30
3-37-63	9	1	11	27	6–30
5-37-63	7	1	14	29	20–30
1-61-39	8	0	0	30	30
3-61-39	9	5	56	28	16–30
5-61-39	9	0	0	30	30
1-65-35	9	1	11	30	28–30
3-65-35	9	4	44	27	17–30
5-65-35	9	6	67	20	7–30
Total or mean	*105*	*24*	*22*	*28*	*6–30*

[a] See Table 1, footnote a.

[b] Calculated as if surviving ducks were all killed on the 30th day (some were actually killed on the 31st day).

Mean survival time (Table 4) includes all ducks that were killed at the end of the experiment but has little meaning in the present experiment, because many ducks were still alive after 30 days. However, these values were used only to calculate average daily loss of body weight and average daily change in PCV and Hb.

Body Weight

Body weight is an indicator of general condition. All surviving ducks progressively lost weight as the experiment continued (Table 5). All groups except the controls and 5-0-100 group weighed less at the end of the experiment than at the midpoint. Weights of controls were essentially the same and weights of the 5-0-100 group were the same at the midpoint and at the end. The controls, 5-0-100 group, and 1-37-63 group weighed 5.0, 5.3, and 6.8 percent, respectively, less at the end of the experiment than at the start. In contrast, groups 3-37-63, 5-37-63, 1-61-39, and 1-65-35 lost from 11.9 to 20.9 percent of their initial body weights. The remaining groups lost from 27.3 to 40.5 percent of their body weight. Ducks dosed with one lead pellet lost the greatest percentage.

Some surviving ducks had lost more than 50 percent of their body weights. Jordan & Bellrose (1951:5) discussed weight loss in lead-poisoned captive wild mallards and stated that "loss of body weight . . . at the time of death may average about 40 per cent of the original weight."

The 1-100-0 group was sixth in total lead eroded and in lead eroded per duck per day (Table 2). Thus, the presence of iron in the shot resulted in a reduction of weight loss. The group of ducks (5-65-35) with the second highest (36.7 percent) average weight loss among surviving ducks (Table 5) was second in lead eroded per day and sixth in iron eroded per duck per day (Table 2).

All ducks were included in the calculations of the mean loss of body weight per duck per day. Again, the two groups having the lowest (1.86 and 2.59 g) daily weight losses were those dosed only with steel shot and the controls. However, the 1-61-39 group was third (4.31 g) in rate of daily weight loss, slightly ahead of the 1-37-63 group (4.72 g). The group dosed with one lead pellet each in the present experiment had the highest daily weight loss (17.15 g).

Weight losses for ducks dosed with one lead pellet in a previous experiment (Sanderson unpublished) have been calculated from data in our files. The mean weight of those 10 ducks was 1.208 kg at the start of the experiment on 22 November. Their average weight at death (an average 17.2 days after being dosed) was 0.800 kg, a 33.8 percent loss at the rate of 23.68 g per duck per day, compared with 40.5 percent and 17.15 g per duck per day in our 1-100-0 group. These latter values break down to 41.7 percent (at an average 21.2 days after being dosed) and 21.46 g per duck per day for the four ducks that died, and 40.5 percent and 14.74 g per duck per day for the five survivors (Tables 5 and 6). These findings indicate that lead-poisoned ducks on a corn diet survive longer and lose more weight during mild weather than during cold weather.

The mean weight of ducks that died (24 ducks, 0.772 kg) was lower than that of ducks that survived for 30 days (81 ducks, 0.890 kg, Table 6). The mean daily weight loss of the ducks that died (24.63 g per duck) was higher than the daily loss (7.79 g) of surviving ducks.

Body Weight in Relation to Lead Dosage.—The mean loss in body weight per duck per day was directly related to the mean amount of lead administered per duck

Table 5.—Mean body weight at start, middle, and end of the experiment; daily change in body weight per duck; and percentage of body weight lost by surviving ducks.

Dose [a]	Mean Body Weight in kg 13 May	28 May	12 June	Mean Daily Weight Loss in Grams per Duck[b]	Percent of Body Weight Lost in 30 Days[c]
0-0-0	1.13	1.06	1.07 (8)[d]	2.6—29[e]	5.0 (8)
1-100-0	1.09	0.86	0.65 (5)	17.2—26	40.5 (5)
5-0-100	1.06	1.01	1.01	1.9—30	5.3 (9)
1-37-63	1.20	1.18	1.12 (8)	4.7—29	6.8 (8)
3-37-63	1.14	1.05 (8)	0.98 (8)	7.0—27	13.5 (8)
5-37-63	1.18 (8)	1.09 (8)	0.96 (6)	6.4—27	15.9 (6)
1-61-39	1.09 (8)	1.06 (8)	0.96 (8)	4.3—30	11.9 (8)
3-61-39	1.08	0.87	0.71 (4)	14.3—28	30.9 (4)
5-61-39	1.20	0.99	0.80	13.4—30	33.3 (9)
1-65-35	1.16	1.03	0.93 (8)	8.6—30	20.9 (8)
3-65-35	1.13	0.96	0.82 (5)	14.0—27	27.3 (5)
5-65-35	1.05	0.84 (7)	0.66 (3)	14.2—20	36.7 (3)
Grand mean	*1.13 (106)*	*1.00 (103)*	*0.89 (81)*	*9.0—28*	*20.7 (81)*

[a] See Table 1, footnote a.

[b] Includes ducks that died during the experiment.

[c] Includes only ducks that survived to the end of the experiment (30 days).

[d] Numbers in parentheses refer to the number of ducks weighed; in all other groups there were nine ducks.

[e] Mean number of days to death.

($P < 0.001$) and the mean amount of lead eroded per duck ($P < 0.005$) per day (Tables 2 and 5). Mean weights of surviving ducks on 28 May and 12 June were inversely related ($P < 0.001$) to lead administered and directly related ($P < 0.001$ and < 0.005, respectively) to mean weight on 13 May. The two groups not dosed with lead (0-0-0 and 5-0-100) lost the least weight per duck per day (2.6 and 1.9 g, respectively, Table 5). Ducks dosed with one lead pellet had the highest daily weight loss (17.2 g), even though this group ranked sixth in total lead administered per duck and mean lead eroded per duck per day. The 3-61-39, 3-65-35, and 5-65-35 groups had similar daily rates of weight loss and ranked third, fourth, and second, respectively, in total lead administered per

Table 6.—Mean body weight and mean loss of body weight per day for ducks that died and ducks that survived.

Dose [a]	Mean Body Weight in kg at Death Survived	Died	Mean Daily Loss of Body Weight in Grams per Duck Survived	Died	Mean Number of Days to Death [b]	Percent of Body Weight Lost by Ducks That Died
0-0-0	1.07 (8)[c]	1.00 (1)	0.77	21.7	23.0	35.5
1-100-0	0.65 (5)	0.64 (4)	14.74	21.5	21.2	41.7
5-0-100	1.01 (9)	. . .	1.86	. . .	. . .	. . .
1-37-63	1.12 (8)	0.64 (1)	3.67	17.0	20.0	34.9
3-37-63	0.98 (8)	0.74 (1)	5.13	81.6	6.0	40.0
5-37-63[d]	0.96 (6)	1.13 (1)	6.03	11.3	20.0	16.7
1-61-39	0.96 (8)	. . .	4.31	. . .	. . .	. . .
3-61-39	0.71 (4)	0.67 (5)	12.25	18.0	25.8	41.0
5-61-39	0.80 (9)	. . .	13.38	. . .	. . .	. . .
1-65-35	0.93 (8)	0.70 (1)	8.21	12.2	28.0	32.6
3-65-35	0.82 (5)	0.64 (4)	10.30	19.8	24.2	42.8
5-65-35	0.66 (3)	0.81 (6)	12.84	18.6	15.7	23.2
Grand mean	*0.89 (81)[d]*	*0.77 (24)*	*7.79*	*24.6*	*20.4*	*34.3*

[a] See Table 1, footnote a.

[b] Ducks that died.

[c] Numbers in parentheses are numbers of ducks in each category.

[d] One duck was accidentally killed during the experiment.

duck. The 5-61-39 group, which was dosed with the largest amount of lead and the third highest amount of iron (Table 2), ranked fifth in rate of daily weight loss. However, we do not conclude that one or more lead-iron shot containing 37–65 percent lead has no effect on daily weight loss.

Ducks dosed with one lead shot lost more weight than ducks dosed with lead-iron shot that eroded more lead (total or daily), and the 5-37-63 group lost less weight than ducks that eroded similar amounts of lead but less iron (Tables 2 and 5). These weight losses suggest that iron provides some protection against weight loss in lead-poisoned ducks on a diet of corn.

Seven groups had noticeably lower daily weight losses than the other five had (Tables 5 and 6). These seven groups lost from 1.9 to 8.6 g per day, compared with 13.4–17.2 g for the remaining five. The seven included both groups that received no lead, all groups that received only one lead-iron shot, and all three that received lead-iron shot containing 63 percent iron.

Thus, ducks dosed with only one lead-iron shot with up to 65 percent lead and 35 percent iron (by weight) seem to have received substantial protection from lead poisoning by some action of the iron. The same conclusion is indicated by the data for ducks dosed with up to five lead-iron shot containing up to 37 percent lead and 63 percent iron. When ducks were dosed with three or more lead-iron pellets containing $\geq$61 percent lead and $\leq$39 percent iron, important weight losses occurred ($\geq$13.4 g per day compared with $\leq$8.6 g per day for all other groups dosed with lead-iron shot). There was no substantial difference between the daily weight loss of controls (2.6 g per duck) and that of ducks dosed with five steel shot (1.9 g). However, the next group (1-61-39) lost 4.3 g per duck per day. The slight difference in daily weight loss between the controls and the group dosed with iron only favored the group dosed with iron (Table 5).

Packed-Cell Volume

Packed-cell volume (PCV) is believed to reflect lead toxicity in ducks. One difficulty is that blood samples can be collected only from live ducks. We observed (Table 6) a greater daily loss of body weight in ducks that died than in those that survived. There may be similar differences in PCV (and Hb), but they cannot be measured.

At the start of the experiment, the mean PCV ranged from 46.2 to 52.2 percent (Table 7). Two weeks later the PCV ranged from 31.6 and 34.1 percent for the 3-61-39 and 1-100-0 groups, respectively, to 52.5 and 52.7 percent for the 5-37-63 and 0-0-0 groups, respectively. At the end of the experiment, values ranged from 31.2 and 34.8 percent for the 1-100-0 and 5-61-39 groups, respectively, to 54.6 and 55.6 percent for the 5-0-100 and 0-0-0 groups, respectively.

The larger the dose of lead, the greater the decline ($P < 0.001$) in PCV during the experiment (Tables 2 and 7). Also, the greater the amount of lead eroded per day, the lower the average PCV at the end of the experiment for surviving ducks (Tables 2 and 7). As with body weight, the PCVs were lower in birds in the 1-100-0 group and higher in birds in the 5-37-63 group than in ducks that were dosed with or eroded similar amounts of lead.

The same seven groups that had relatively low weight losses (Table 5) also had high PCVs at the end of the experiment (Table 7), values that were not appreciably lower (in three groups they were higher) at the end of the experiment than at the beginning. In the remaining five groups (1-100-0, 3-61-39, 5-61-39, 3-65-35, and 5-65-35), the PCVs were markedly lower at the end of the experi-

Table 7.—Mean packed-cell volume (PCV) and hemoglobin (Hb) values at the start, middle, and end of the experiment and daily changes in PCV and Hb values per duck.

Dose[a]	Mean PCV (Percent)			Mean Daily Change in PCV per Duck (Percent)[b]	Mean Hb Value (g/100 ml)			Mean Daily Change in Hb per Duck (Percent)[b]
	13 May	28 May	12 June		13 May	28 May	12 June	
0-0-0	48.3	52.7	55.6 (8)[c]	+ 0.275	14.12	15.48	15.25 (8)	+ 0.053
1-100-0	46.2	34.1	31.2 (5)	– 0.547	14.40 (5)	7.88	9.72 (5)	– 0.071
5-0-100	48.8	50.3	54.6	+ 0.192	14.68 (5)	16.01	17.28	+ 0.091
1-37-63	47.6	49.6	51.9 (8)	+ 0.042	14.70 (7)	12.58	14.65 (8)	0.000
3-37-63	50.2	50.2 (8)	48.6 (8)	+ 0.033	13.39	12.55 (8)	14.94 (8)	+ 0.034
5-37-63	50.8 (8)	52.5 (8)	45.5 (6)	– 0.144	14.58 (8)	14.31 (8)	12.03 (6)	– 0.095
1-61-39	52.2	50.8 (8)	49.9 (8)	– 0.021	14.19	13.90 (8)	14.29 (8)	+ 0.005
3-61-39	46.9	31.6	36.2 (4)	– 0.225	14.48 (4)	7.94	10.70 (4)	– 0.037
5-61-39	51.0	41.1	34.8	– 0.541	15.10 (7)	9.62	8.54	– 0.231
1-65-35	46.2	46.7	46.0 (8)	+ 0.033	13.51	11.42	12.38 (8)	– 0.025
3-65-35	49.9	41.4	35.4 (5)	– 0.440	14.75 (6)	10.21	8.38 (5)	– 0.164
5-65-35	49.8	41.8 (7)	40.0 (3)	– 0.311	14.14 (7)	10.71 (7)	10.13 (3)	– 0.096
Grand mean	*49.0*	*45.2*	*44.1*	*– 0.138*	*14.34*	*11.88*	*12.36*	*– 0.045*

[a] See Table 1, footnote a.

[b] Includes only ducks surviving on 12 June.

[c] Numbers in parentheses are numbers of ducks in groups. All other groups numbered nine ducks.

ment than at the beginning. Thus, the PCVs also indicate that ducks receive substantial protection against lead poisoning from one lead-iron shot with up to 65 percent lead and 35 percent iron and from up to five lead-iron shot containing 37 percent lead and 63 percent iron, but ducks dosed with three or more lead-iron pellets containing 61 percent or more lead and 39 percent or less iron had reduced PCVs. Compared with the controls and ducks dosed exclusively with steel shot, all groups had a modest reduction in PCVs. Again, we do not conclude that even one lead-iron pellet containing as little as 37 percent lead has no effect.

PCVs at the end of the experiment and the mean change in PCV during the experiment were not appreciably different in the controls and in ducks dosed with five steel pellets (Table 7). PCVs increased slightly in both groups but increased more in the controls.

PCV IN RELATION TO LEAD DOSAGE.—The PCVs of the ducks that survived to the end of the experiment were higher in five groups at the end of the experiment than they were at the start, perhaps indicating that these ducks were better conditioned to captivity at the end of the experiment (Table 7). Only in controls and in ducks dosed only with steel pellets were the daily increases in PCVs substantial. Changes in PCVs in five other groups were a slight daily increase in groups 1-37-63 (0.042 percent), 3-37-63 (0.033 percent), and 1-65-35 (0.033 percent); a slight daily decrease in group 1-61-39 (– 0.021 percent); and an intermediate daily decrease in group 5-37-63 (– 0.144 percent).

The remaining six groups showed larger daily decreases in PCVs ranging from – 0.225 to – 0.547 percent (Table 7). The group dosed with one lead shot showed the greatest daily decrease. The same seven groups of ducks that showed the lowest daily weight losses (Table 5) and the highest PCVs (Table 7) at the end of the experiment also showed the smallest decreases (five showed increases) in PCVs. With slight deviations, group rank in weight loss, actual PCV, and change in PCV were the same (Table 8).

These data further indicate the protective value of iron against lead toxicity in ducks, one lead-iron pellet of up to 65 percent lead and 35 percent iron and three pellets of 37 percent lead and 63 percent iron having only slight effects. Although the 5-37-63 and 3-61-39 groups eroded similar amounts of lead daily (0.0054 and 0.0057 g, respectively), the first also eroded 0.009 g of iron daily compared with 0.004 g of iron for the second (Table 2). These two groups had daily decreases in PCVs of – 0.144 and – 0.225 percent, respectively (Table 7). We conclude that, as with total weight change and total change in PCV, all levels of lead administered caused detectable differences in daily changes in PCV, even in the presence of iron.

Hemoglobin

As with PCV, a reduction in hemoglobin (Hb) is believed to reflect lead toxicity. At the start of the experiment, mean Hb for the various groups ranged from 13.4 (g per 100 ml) to 15.1, and the grand mean was 14.2. Two weeks later Hb ranged from 7.9 for the 1-100-0 and 3-61-39 groups to 15.5 and 16.0 for the controls and ducks dosed only with steel shot, respectively (Table 7). At the end, Hb ranged from 8.4 and 8.5 for the 3-65-35 and 5-61-39 groups, respectively, to 15.2 and 17.3 for the controls and ducks dosed only with steel shot, respectively. Hb for the ducks dosed with one lead pellet (9.7) was slightly higher at the end of the experiment than it had been 2 weeks earlier.

Table 8.—Rankings of treatment groups for 18 characters (most favorable condition received the lowest score).

	Character[b]																			Order
Dose[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total	of Total
0-0-0	4	3	2	2	1	1	1	1	2	2	2	3	9	1	2	3	2	6	47	1
1-100-0	9	11	12	12	12	11	12	12	12	10	8	12	12	12	11	12	3	9	192	12
5-0-100	1	7	3	1	2	4	2	2	1	1	1	4	1	3	5	10	1	1	50	2
1-37-63	4	1	1	4	3	7	3	3	5	4	5	2	2	4	8	1	6	2	65	3
3-37-63	4	5	4	6	5	6	5	4	6	3	3	6	6	2	1	2	8	3	79	4
5-37-63	8	2	6	5	6	2	7	7	3	7	9	1	7	5	3	5	11	8	102	6
1-61-39	1	4	5	3	4	3	4	6	4	5	4	5	3	10	7	6	7	4	85	5
3-61-39	11	10	10	11	10	12	9	8	11	8	7	7	4	8	9	9	9	10	163	9
5-61-39	1	8	9	8	9	10	11	11	10	11	12	8	5	9	4	7	10	7	150	8
1-65-35	4	6	7	7	7	4	6	4	7	6	6	11	8	6	5	8	5	5	112	7
3-65-35	9	9	8	9	8	9	10	10	9	12	11	10	11	11	12	11	4	11	174	11
5-65-35	12	12	11	10	11	8	8	9	8	9	10	9	10	7	10	4	12	12	172	10

[a] See Table 1, footnote a.

[b] 1. Percentage of mortality within 30 days.
2. Mean body weight on 28 May.
3. Mean body weight on 12 June.
4. Mean daily loss of body weight per duck.
5. Percentage of body weight lost in 30 days (surviving ducks only).
6. Percentage of PCV on 28 May.
7. Percentage of PCV on 12 June.
8. Mean daily change in PCV per duck.
9. Mean Hb on 28 May.
10. Mean Hb on 12 June.
11. Mean daily change in Hb per duck.
12. Testes weight.
13. Thyroid weight.
14. Spleen weight.
15. Pancreas weight.
16. Liver weight.
17. Kidney weight.
18. Adrenal weight.

Note: Ties are given equal numbers. Low weights for kidneys and adrenals are considered desirable.

The more lead administered per duck, the lower the average Hb ($P < 0.001$) in surviving ducks at the end of the experiment. Also, the higher the Hb at the start (13 May), the larger the decline ($P < 0.001$) in Hb during the experiment, but there was a significant positive correlation ($P < 0.05$) between the amount of Hb at the beginning and at the end of the experiment (Table 7).

The same seven groups of ducks that had relatively low weight losses (Table 5) and high PCVs (Table 7) also had high Hb at the end of the experiment, values that were not appreciably lower (four groups were higher) at the end of the experiment than at the beginning. In the remaining five groups (3-65-35, 5-61-39, 1-100-0, 5-65-35, and 3-61-39), Hb was lower at the end of the experiment than at the beginning. Thus, Hb also supports the conclusions and statements indicated by weight loss and PCV.

HB IN RELATION TO LEAD DOSAGE.—In four groups, Hb was higher at the end of the experiment than at the start in ducks surviving to the end of the experiment, perhaps indicating that these ducks were better conditioned to captivity at the end of the experiment (Table 7). However, the only substantial increases were in the 5-0-100, 0-0-0, and 3-37-63 groups. The first two of these groups also showed increases in PCVs. In calculating the mean daily change in Hb per duck from the start of the experiment to the end, only ducks alive at the end of the experiment were included. However, in calculating the mean Hb for the start, middle, and end of the experiment, all ducks alive at the respective dates and for which we had suitable blood samples were included. Several blood samples collected on 13 May hemolyzed and were not suitable for Hb determinations. Hb increased slightly in group 1-61-39, was unchanged in group 1-37-63, and decreased slightly in groups 1-65-35 and 3-61-39.

The remaining five groups showed daily percentage decreases in Hb ranging from −0.071 to −0.231. The group dosed with five pellets containing 61 percent lead showed the greatest daily decrease. This group also eroded the most lead per duck per day (Table 2). The same seven groups of ducks showing the lowest daily weight losses (Table 5) and the highest PCVs at the end of the experiment (Table 7) also had the highest Hb values at the end. Except for the 5-37-63 group, the same seven groups also showed the slightest decreases (four groups showed increases) in Hb. As with changes in weight, PCV, and total Hb, lead caused daily changes in Hb even in the presence of iron.

The 5-37-63 group showed Hb values superior to those of the 5-61-39 group, but not to those of the 5-65-35 group, in the mean daily change in Hb per duck. The Hb of the six surviving ducks in the 5-37-63 group was higher than the Hb of the surviving ducks in the 3-61-39, 5-65-35, 1-100-0, 5-61-39, and 3-65-35 groups (Table 7). Hb in the surviving ducks dosed with five pellets containing 37 percent lead and 63 percent iron declined relatively more than change in weight and PCV. However, the decrease in Hb in the 5-37-63 group was caused by exceptionally low values in two of the six surviving ducks. Thus, Hb in most ducks declined only slightly when five pellets containing 37 percent lead and 63 percent iron were ingested. Hb at the end of the experiment was slightly higher and the daily increase in Hb was greater in ducks dosed with five soft steel pellets than in the controls.

Weight of Testes

The weights of both testes for the 12 groups of ducks ranged from a low of 0.368 g for the group dosed with one lead pellet to 1.333, 1.401, 1.679, and 2.420 g for groups 5-0-100, 0-0-0, 1-37-63, and 5-37-63, respectively (Table

Table 9.—Mean organ weights.

Dose[a]	Testes (g)	Thyroid (mg)	Spleen (mg)	Pancreas (g)	Liver (g)	Kidneys (g)	Adrenals (mg)
0-0-0	1.40	44	928	1.60	19.2	4.6	149
1-100-0	0.37	36[b]	223	1.13	10.7	4.8	173
5-0-100	1.33	101	687	1.48	14.9	3.8	100
1-37-63	1.68	84	601[c]	1.36	23.8	5.0	118
3-37-63	0.78	59[b]	868	1.63	20.7	5.0	131
5-37-63	0.93[d]	57[e]	542[b]	1.54[b]	17.5[b]	5.6[b]	161[b]
1-61-39[b]	0.94	79	410	1.47	16.1	5.0	131
3-61-39	0.59	46	429	1.34	15.5	5.2	178
5-61-39	0.45	60	420	1.51	15.8	5.5	149
1-65-35	0.38	52	535[b]	1.48	15.8	4.9	143
3-65-35	0.39	38	311	1.07	12.3	4.7	180
5-65-35	0.43	42[e]	485	1.32	18.9	6.0	220
Grand mean	*0.80*	*58*	*536*	*1.41*	*16.8*	*5.0*	*153*

[a] See Table 1, footnote a.

[b] Eight organ weights; unless indicated otherwise, nine organs were weighed in each group.

[c] One spleen in this group weighed 9,891.9 mg, more than the spleens from the other eight ducks in this group combined. If this large spleen were included, the mean weight would be 1,633.39 mg.

[d] The testes of one duck in this group weighed 12.83 g, more than the testes of the other seven ducks in this group combined. If these large testes were included, the mean weight for this group would be 2.42 g.

[e] Seven thyroids.

9). The 5-37-63 group had the highest mean weight, perhaps because the testes from one duck in the group weighed 12.83 g, more than three times as much as the testes of any other duck in the same group. If these testes are omitted, the mean weight of both testes is only 0.933 g.

The normal seasonal cycle of gonad weights in wild male mallards has apparently not been studied. The mean weight of both testes of two mallards collected during February and March in one of the royal parks in London was 13.10 g (Höhn 1947:288), and the mean weight of both testes of three mallards collected during May at the same location was 15.88 g. Sanderson (unpublished) found that the total weight of the testes of one captive wild mallard in a control group was 2.0 g on 2 March; the mean weight was 10.28 g for the two testes from each of 12 ducks dosed with copper shot and sacrificed 160 days later on 1 May 1973, the greatest weight being 19.1 g. Two factors, which may have inhibited the normal growth of testes in ducks used in that experiment, were the dosage of copper shot and a corn diet for the first 100 days (to 2 March). On day 100 the ducks were placed on an improved diet.

In the present experiment, it appears that either the effects of captivity or diet, or both, inhibited the normal growth of the testes. There was a negative, but not significant ($P > 0.05$), linear relationship between the amount of lead administered and weight of the testes at the end of the experiment. The heaviest testes were the pair in group 5-37-63, mentioned previously, that weighed 12.83 g on 28 May. The second heaviest pair were from a duck in group 1-37-63 and weighed 7.05 g on 12 June. No other pair weighed as much as 5.0 g, and only two pairs exceeded 4.0 g.

Apparently the effects of diet or captivity, or both, which inhibited normal growth of the testes, prevented the amount of lead administered from showing a significant effect on testis weight. However, the correlation was negative; histology indicated that lead had an adverse effect on spermatogenesis; and the ducks in the group dosed with one lead pellet had the lightest testes, a finding similar to the findings about several other parameters measured. The seven groups with the highest mean weights of testes included the usual groups (0-0-0, 5-0-100, and all ducks dosed with one lead-iron shot) except that the 1-65-35 group had next to the smallest testes (0.381 g) and was replaced in the top seven groups by the 3-61-39 group. It appears that the mean testis weight of wild mallards on a diet of corn in captivity is not a sensitive indicator of lead toxicity.

Weight of Thyroids

Weights of thyroids ranged from 36.1 mg for ducks dosed with one lead pellet up to 101.1 mg for ducks dosed with five steel pellets (Table 9). The usual seven groups had the heaviest thyroids except that the control group was replaced by the 5-61-39 group. The contrast between the thyroid weights of the two groups not dosed with lead (the controls and the 5-0-100 group) is striking—44.26 mg for the controls compared with 101.13 mg for the group dosed with steel pellets. There was no significant ($P > 0.05$) correlation between thyroid size and amount of lead administered or between thyroid size and any other of our measurements. We have no explanation for the large size of the thyroids of ducks dosed with steel shot. In a later study with game-farm mallards, Sanderson found no significant effect of ingested steel shot on the size of thyroids (Sanderson unpublished).

Weight of Spleen

Mean weights of spleens ranged from 222.9 mg for ducks dosed with one lead pellet to 928.4 mg for controls. The usual seven groups had the heaviest spleens except that the 5-65-35 group replaced the 1-61-39 group. Although the difference in weights of the spleens of the two groups not dosed with lead was appreciable, on a relative basis it was not as striking as the difference in thyroid weights—thyroids of the 5-0-100 ducks weighed 130 percent more than thyroids of controls, but spleens of the 5-0-100 ducks weighed 26 percent less than spleens of controls.

In most groups the spleen weights were highly variable, but there were few significant differences among groups. There was a significant ($P < 0.005$) negative correlation between the amount of lead administered and the weight of the spleen.

Weight of Pancreas

Mean weights of the pancreas varied from 1.07 g for the 3-65-35 group to 1.63 g for the 3-37-63 group (Table 9). The usual seven groups had the heaviest pancreases except that the 5-61-39 group ranked fourth (1.51 g) ahead of ducks dosed only with steel shot (1.48 g) and ducks in the 1-65-35 group (1.48 g). The pancreases of the group dosed with one lead pellet (1.13 g) averaged only slightly heavier than those of the 3-65-35 group (1.07 g). Also, there was little difference in the mean weights of the pancreases in the controls (1.60 g) and the 5-0-100 group (1.48 g). There was a significant ($P < 0.005$) negative correlation between the amount of lead administered and the weight of the pancreas. However, the 5-61-39 group ranked fourth in weight of the pancreas but had the most total lead eroded and the most lead eroded daily per duck (Table 2). The same group had the third highest total amount and daily amount of iron eroded per duck. Thus, simultaneous high levels of lead and iron appeared to have less effect on the pancreas than lower levels of lead had when smaller amounts of iron were administered.

Weight of Liver

Mean weights of the liver varied from 10.7 for the 1-100-0 group to 23.8 g for the 1-37-63 group. Livers of groups dosed with lead shot only (10.7 g) and with steel shot only (14.9 g) both averaged less than the mean liver weight (16.8 g) of all ducks (Table 9). Livers of ducks in the 1-37-63 group (23.8 g) and in the 3-37-63 group (20.7 g) had higher mean weights than livers of control ducks (19.2 g). Thus, it appears that dosing with lead shot or with steel shot caused a greater reduction in liver weight than did most lead-iron pellet doses. There was a significant ($P < 0.001$) negative correlation between the amount of lead administered and the weight of the liver. Livers of ducks dosed with five steel pellets weighed less than livers of controls.

Weight of Kidneys

The combined mean weight of both kidneys ranged from 3.8 g (5-0-100) to 6.0 g (5-65-35). Although the weights of kidneys of controls were little different from those of six other groups (1-100-0, 3-65-35, 1-65-35, 1-37-63, 1-61-39, and 3-37-63) or from the mean weight of all kidneys (Table 9), there was a significant ($P < 0.02$) positive relationship between the amount of lead administered and kidney weight. All groups dosed with five lead-iron pellets and the 3-61-39 group had kidneys that weighed more than the kidneys of controls and more than the mean weight of all kidneys. Kidneys of the group dosed only with steel pellets weighed less than the kidneys of any other group.

Weight of Adrenals

The mean weight of the adrenals ranged from 100.1 mg (5-0-100) to 220.1 mg (5-65-35). As with the kidneys, the adrenals of ducks dosed only with steel pellets weighed less than the adrenals of any other group (Table 9). There was a significant ($P < 0.001$) positive linear relationship between the amount of lead administered and the mean weight of the adrenals. Adrenals of five groups of ducks weighed substantially more and of four groups substantially less than the mean weight of adrenals of controls (Table 9). Except for ducks dosed with steel shot only, all ducks whose adrenals weighed substantially less than adrenals of controls were dosed with low levels of both lead and iron.

Ratio of Iron to Lead Eroded

The ratio of iron to lead in the pellets (Table 2) appears to be as important as the amount of lead eroded per day as measured by the mean daily rate of weight loss. For example, ducks in groups 5-37-63 and 3-61-39 eroded similar amounts of lead per day, but the ratio of iron to lead eroded daily was nearly three times as high in the 5-37-63 group as in the 3-61-39 group. The daily weight loss in the 5-37-63 group was only 44.8 percent of the rate in the 3-61-39 group (Table 5). Also, daily amounts of lead eroded were similar in the 1-37-63 group (0.0013 g per day) and in 1-65-35 (0.0019 g per day), but the ratio of iron to lead eroded was more than three times higher in the former group. Daily weight losses in the 1-37-63 group were only 54.7 percent of the losses in the 1-65-35 group.

Lead and Iron Residues in the Liver

The lead in livers of two ducks from each group (Table 10) averaged from 1.4 and 2.2 ppm (wet weight), respectively, for the controls and the group dosed only with steel shot to a high of 54.9 ppm for the 5-61-39 group. Ducks in the 5-61-39 group by far eroded the most lead. There was a significant ($P < 0.001$) positive correlation between the amount of lead eroded and ppm of lead in the liver. Iron eroded tended to be negatively associated with amount of lead in the liver, but the association was not significant ($P > 0.40$). It may be that iron helps to mitigate the effects of lead poisoning in ducks by decreasing the absorption of lead or increasing its excretion, or both.

Livers of two ducks from each group averaged from 775 to 4,000 ppm of iron (wet weight), respectively, for the controls and the 3-65-35 group. The latter group eroded less than the average amount of iron. Ducks dosed only with steel shot eroded the most iron but had only 2,140 ppm of iron in their livers compared with a mean of 2,657 ppm of iron for all livers. There were negative but not significant correlations between the amount of iron eroded and the concentration of iron ($P > 0.25$) and total iron in the liver ($P > 0.50$). However, the reason that these relationships were not significant is probably that ducks dosed with high levels of lead had high levels of iron (both ppm and total amount of iron) in their livers. For

Table 10.—Lead and iron in the liver and the mean amount of lead and iron eroded daily per duck; two ducks were in each group.

Dose[a]	Mean ppm of Lead in Liver (Wet Weight)	Mean Lead Eroded in Grams	Mean ppm of Iron in Liver (Wet Weight)	Mean Iron Eroded in Grams	Mean Total Iron in Liver in mg
0-0-0	1.4	0.000	775	0.000	13.8
1-100-0	41.6	0.108	3,875	0.000	46.3
5-0-100	2.2	0.000	2,140	0.255	23.3
1-37-63	11.3	0.044	1,380	0.076	21.7
3-37-63	36.3	0.097	2,550	0.167	35.5
5-37-63	20.8	0.128	1,515	0.221	26.8
1-61-39	29.6	0.069	2,500	0.044	35.1
3-61-39	33.2	0.144	3,925	0.092	36.1
5-61-39	54.9	0.383	2,695	0.246	45.7
1-65-35	16.4	0.064	3,346	0.035	49.4
3-65-35	32.2	0.140	4,000	0.077	44.6
5-65-35	29.9	0.118	3,180	0.065	34.8
Grand mean	*25.8*	*0.108*	*2,657*	*0.106*	*34.4*

[a] See Table 1, footnote a.

Table 11.—Lead in the blood; two ducks were in each group.

Dose[a]	Mean ppm of Lead in Blood (Wet Weight)		
	13 May	28 May	12 June
0-0-0	0.35	0.67	0.83
1-100-0	0.26	4.50	7.50
5-0-100	0.14	0.50	0.96
1-37-63	0.52	3.92	3.98
3-37-63	0.42	10.24	10.64
5-37-63	0.51	7.75	10.30
1-61-39	0.54	11.41	7.42
3-61-39	0.32	6.28	5.66
5-61-39	0.40	22.28	15.95
1-65-35	0.62	3.90	3.22
3-65-35	0.34	13.15	9.83
5-65-35	0.33	31.24	5.99
Grand mean	*0.40*	*9.66*	*6.86*

[a] See Table 1, footnote a.

example, the 1-100-0 ducks had almost as high a concentration (3,875 ppm) of iron in their livers as the two groups with the highest concentrations of iron—3-65-35 (4,000 ppm) and 3-61-39 (3,925 ppm). The 1-100-0 ducks had the second highest total iron (46.3 mg) in their livers after the 1-65-35 ducks (49.4 mg). There was a positive, but not significant, relationship between the amount of iron administered and the concentration and total iron in the livers of controls, the 5-0-100 group, and the three groups of ducks dosed with shot that were 37 percent iron.

Lead in the Blood

Lead in the blood of two ducks from each group was determined on the day when pellets were administered and 2 and 4 weeks later. It was higher in all groups 2 weeks after dosing than at dosing (Table 11). However, lead residues in the 5-0-100 and 0-0-0 groups increased only slightly compared with increases in groups dosed with shot containing lead. Lead in the blood of all but one group was essentially the same 4 weeks after dosing as it was after 2 weeks. One duck in the 5-65-35 group showed a sharp decline in lead in the blood from 2 to 4 weeks after dosing, which we cannot explain. Both samples were analyzed twice with similar results. There was a positive relationship ($P < 0.001$) between mean weight of lead eroded and lead in the blood 4 weeks after dosing.

Iron eroded (Table 2) appeared to have little relation to the lead concentration in the blood (Table 11). In contrast, lead, administered either in lead shot or in lead-iron shot, caused substantial increases in concentration and total iron in the liver (Table 10).

Histopathology of Organs

Abnormal changes occurred in liver, spleen, kidneys, and testes regardless of the concentration of lead, but the changes related to the amounts of lead. Hemosiderosis was found in the spleens and livers of all ducks except the controls. Intranuclear inclusion bodies were found in the kidney tubule cells of all birds dosed with lead. Bone structure was normal in all groups. Gonad, spleen, liver, and kidneys showed histological variation from group to group.

Testes.—Testes of controls and birds dosed only with steel shot showed active spermatogenesis. Sperm were present in all microscopic fields, and interstitial tissue was well developed. No duck in any other group showed evidence of spermatogenesis. The seminiferous tubules were, in most cases, poorly differentiated by the interstitium.

Spleen.—Spleens of the two control ducks appeared normal. Birds in the 5-0-100 group had spleens containing a granular pigment, possibly a siderin (iron-containing complex), deposited in both the red and white pulp. All ducks dosed with lead had a moderate amount of granular pigment deposited throughout the spleen. Large amounts of pigment were found in the spleens of the ducks in the 3-61-39 group.

Liver.—Liver sections from controls were not typical of normal liver. Both livers showed vacuolation of hepatocytes, possibly as a result of glycogen storage or as part of a degenerative process, probably both. Livers from birds in the 5-0-100 group showed vacuolation of hepatocytes as well as deposition of a granular pigment similar in appearance to that found in the spleen. Both livers in the 1-37-63 group showed vacuolation of hepatocytes but no pigment deposition. Neither liver from the ducks in the 1-61-39 group showed vacuolation, but one (No. 154) had moderate amounts of pigment deposition. One duck of the 1-65-35 group had vacuolated hepatocytes, and both had pigment deposition in moderate amounts.

One bird from the 3-37-63 group had a normal liver. The other showed pigment deposition, but no vacuolation, and slight necrosis of hepatocytes. Necrosis may have occurred postmortem due to improper fixation of the tissues, but it is known to be an antemortem sign of lead intoxication.

In the other experimental groups, most ducks showed moderate pigment deposition and necrosis of hepatocytes. The necrosis obscured any vacuolation that might have been present by obliterating cellular boundaries. Two exceptions were the ducks of the 5-65-35 group, which, although showing heavy pigment deposition, showed no necrosis or vacuolation of hepatocytes. One duck in the 3-65-35 group had extensive cirrhosis of the liver in addition to pigment deposits and necrosis.

Kidneys.—Intranuclear inclusion bodies were present in the proximal tubule cells of the kidneys of most of the groups of mallards dosed with lead (Table 12). The controls and ducks in the 5-0-100 and 1-61-39 groups had no inclusion bodies, and the kidneys appeared morphologically normal. One duck in the 5-65-35 group also had no inclusion bodies in the nuclei, but there was some degenerative change in the tubule cells.

The significance of the inclusion bodies is not known. Chronic nephritis is a common finding in mammalian

Table 12.—Number of intranuclear inclusion bodies in proximal tubule cells of the kidneys.

Dose[a]	Number of Ducks	Average Number of Inclusions per Oil Immersion Field
0-0-0	2	0
1-100-0	3	30
5-0-100	2	0
1-37-63	2	3
3-37-63	2	10
5-37-63	3	9
1-61-39	2	0
3-61-39	3	23
5-61-39	2	20
1-65-35	2	4
3-65-35	3	32
5-65-35	4	7

[a] See Table 1, footnote a.

chronic lead poisoning but has not been related to the presence of inclusion bodies in the proximal tubule cells (National Academy of Sciences 1972).

Hematology

The controls and birds in the 5-0-100 group showed a relatively constant blood picture throughout the experiment. There were few reticulocytes, and most red and white cells were normal in shape, size, and color. Platelet numbers appeared to be normal, judging from the predosage values.

Because changes over the 4-week period were similar among the groups dosed with varying amounts of lead and differed only in degree (which is difficult to evaluate), these groups are discussed in terms of the two extremes—1-100-0 and 1-37-63. Ducks in the 1-100-0 group showed the greatest changes over the 4-week period. Reticulocytes increased from baseline levels of approximately 5–6 percent of the red cell population to, in some cases, full fields of reticulocytes, poikilocytes, and anisocytes. White cells appeared normal, but differential counts were not performed. Platelets varied erratically in number. Some ducks had very few, others far more than the usual number.

The ducks in the 1-37-63 group showed few changes. The second and third samples contained more reticulocytes than the first. Approximately 15 percent of the red blood cells in the third sample were immature, as compared with 5 or 6 percent in the predosage samples and in control ducks. White blood cells and platelets appeared normal. Blood from ducks dosed with lead is typical of that of ducks suffering varying degrees of anemia.

Ordering of Groups

We ranked the 12 groups of ducks in numerical order from 18 characters (Table 8). The condition considered most desirable (usually the highest value, but in some cases the lowest value) was designated by 1. Ties were given equal values. The total scores increased relatively evenly from the first group (controls) to the seventh and from the eighth to the twelfth, but a large increase occurred between the seventh group and the eighth.

SUGGESTIONS FOR FUTURE RESEARCH

Body weight, PCV, and Hb were all significantly correlated with the amount of lead administered. PCV and Hb gave similar results, but PCV is easier to determine. Only limited information regarding the effects of lead was gained from the weights of organs (most were variable) and from the histopathology studies.

Adequate data about the effects of lead-iron shot in captive mallards may be the mortality rate after 6 weeks and body weight and PCV at 2, 4, and 6 weeks. Such a regime would reduce handling of the ducks, which could be banded when randomly assigned to dosage groups. It would be necessary only to dose the ducks and, at 2, 4, and 6 weeks, to weigh them and take blood samples for PCV determinations.

LITERATURE CITED

Anderson, William L. 1975. Lead poisoning in waterfowl at Rice Lake, Illinois. Journal of Wildlife Management 39:264–270.

Bellrose, F. C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Natural History Survey Bulletin 27:235–288.

Cook, R. S., and D. O. Trainer. 1966. Experimental lead poisoning of Canada geese. Journal of Wildlife Management 30:1–8.

Höhn, E. O. 1947. Sexual behaviour and seasonal changes in the gonads and adrenals of the mallard. Zoological Society of London Proceedings, 117 (Parts II and III): 281–304.

Irwin, J. C., D. Dennis, and N. G. Perret. 1974. Lead-iron shot, a possible solution to the lead-poisoning problem in waterfowl: further toxicity information. Northeast Fish and Wildlife Conference Transactions 31:159–171.

Jordan, J. S., and F. C. Bellrose. 1950. Shot alloys and lead poisoning in waterfowl. North American Wildlife Conference Transactions 15:155–168.

______, and ______. 1951. Lead poisoning in wild waterfowl. Illinois Natural History Survey Biological Notes 26. 27 p.

Luna, L. G., ed. 1968. Manual of histologic staining methods of the Armed Forces Institute of Pathology. 3rd ed. Blakiston Division, McGraw-Hill Book Co., New York. 258 p.

National Academy of Sciences. 1972. Lead: airborne lead in perspective. 348 p.

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HE LIFE HISTORY OF THE TENNESSEE NUBNOSE DARTER, *Etheostoma simoterum* N BRUSH CREEK, TENNESSEE

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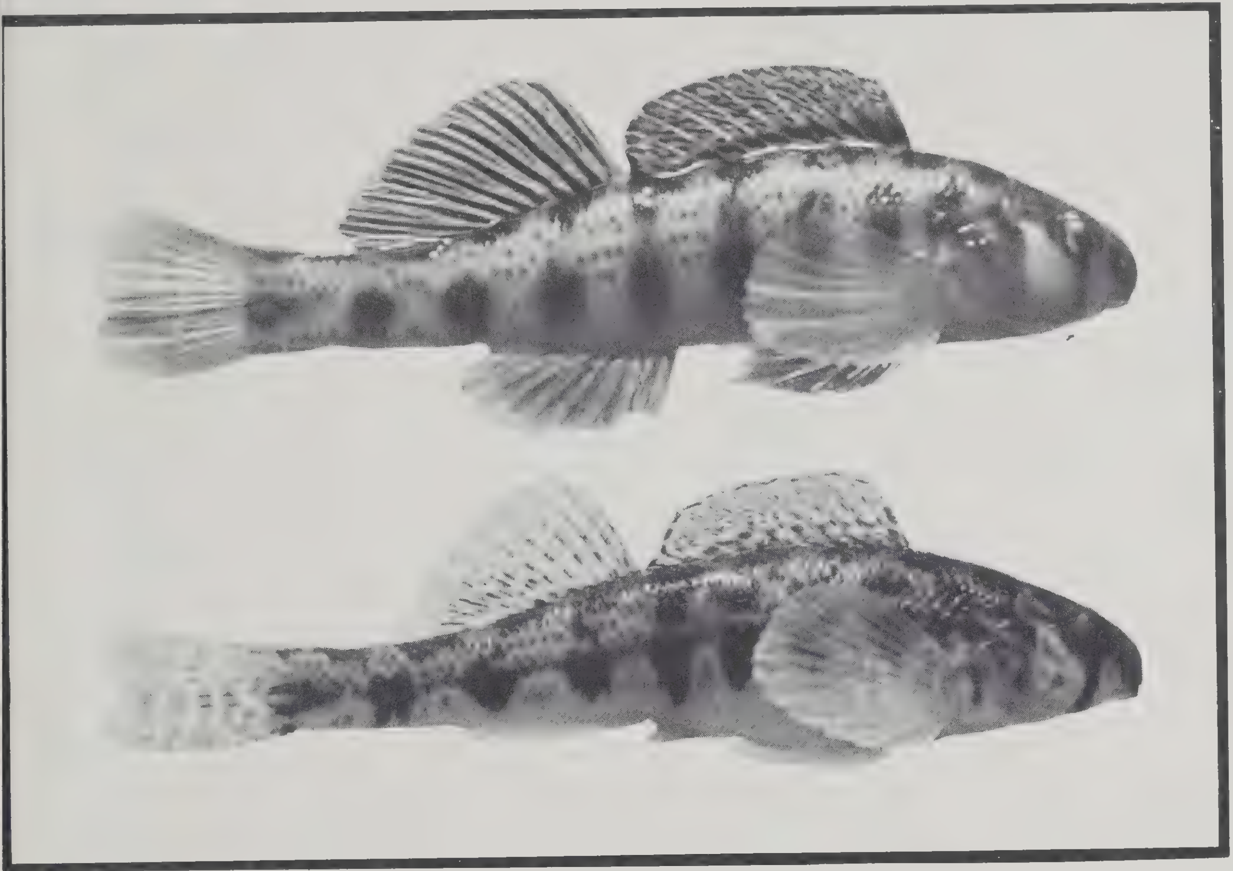

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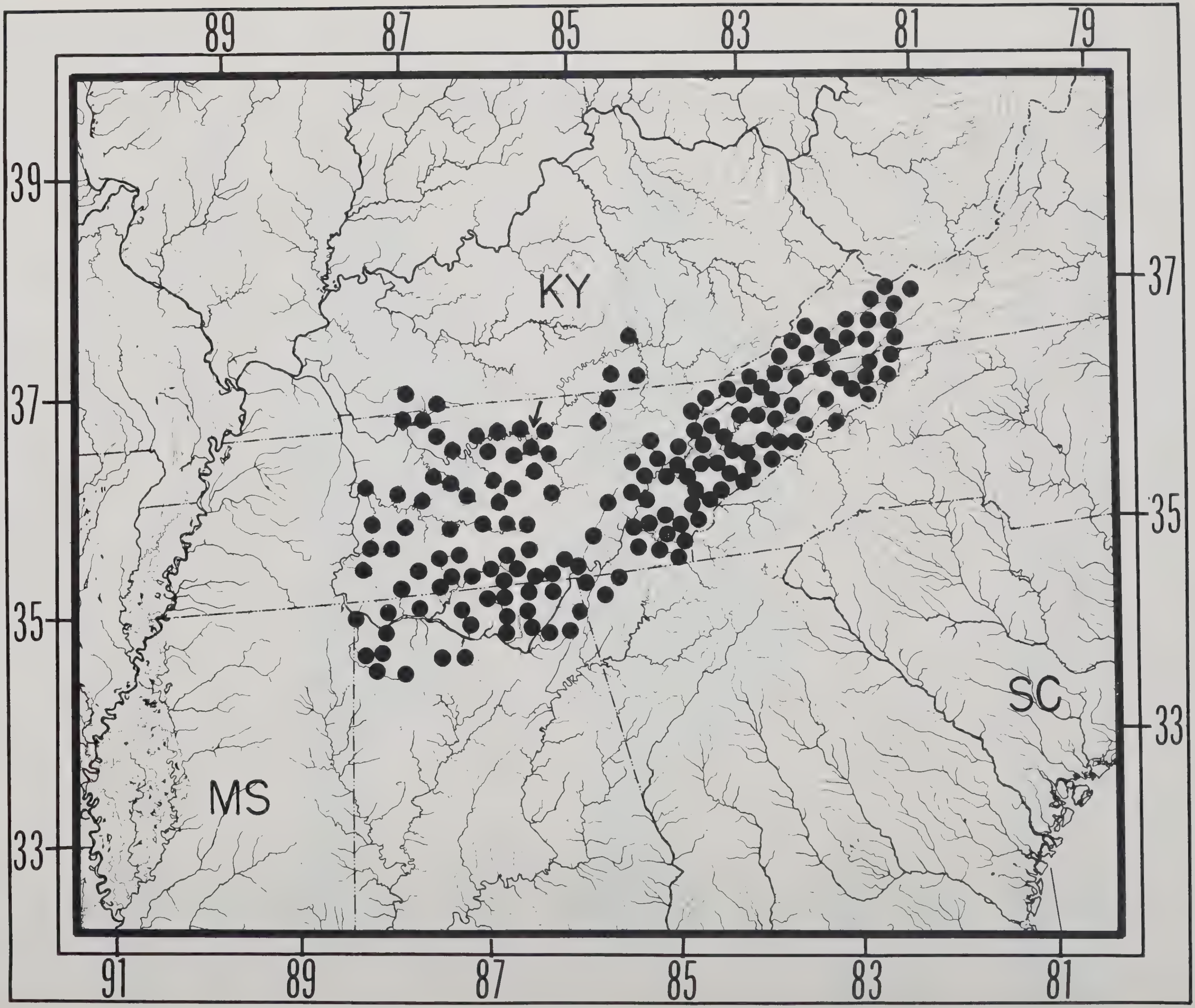

Fig. 1. Distribution of *Etheostoma simoterum*. The arrow points to the study site.

The Life History of the Tennessee Snubnose Darter, *Etheostoma simoterum*, in Brush Creek, Tennessee

Lawrence M. Page and Richard L. Mayden

The Cumberland snubnose darter, described as *Arlina atripinnis* by D. S. Jordan in 1877 from specimens collected near Nashville, Tennessee, has been determined recently to be at most only intraspecifically distinct from the Tennessee snubnose darter, *Etheostoma simoterum* (Cope) (D. A. Etnier, personal communication), as suggested by Bouchard (1977:129). *Etheostoma simoterum,* described as *Hyostoma simoterum* from the Holston River, Virginia, by E. D. Cope in 1868 thus ranges throughout most of the Tennessee River system and much of the Cumberland River system (Fig. 1).

The subgenus *Nanostoma* of *Etheostoma* encompasses *Etheostoma zonale* and all species previously referred to the subgenus *Ulocentra* (Page 1981), including *E. simoterum.* Except for *E. zonale* and *E. coosae,* all species in *Nanostoma* are poorly known ecologically. The lack of information on these species is in part because 9 of the 15 recognized species in the subgenus are undescribed taxonomically; without names, species remain unknown except to a few specialists. Ecological data on *E. zonale* are included in Forbes & Richardson 1908:306; Lachner et al. 1950; Miller & Robison 1973:216; Wehnes 1973; Adamson & Wissing 1977; Pflieger 1975:312; Lutterbie 1979:24; Bryant 1979; and Cordes & Page 1980. The life history of *E. coosae* was studied recently in Barbaree Creek, Clay County, Alabama (O'Neil & Boschung 1980:53). Bouchard (1977) discussed the habitats utilized by *E. etnieri.*

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STUDY AREA AND METHODS

Etheostoma simoterum was studied in Brush Creek, Smith County, Tennessee at the same site used in the life-history study of *E. olivaceum* and described by Page (1980:3–5). The Brush Creek population of *E. simoterum* is referred to by Page (1980) as *E. atripinne.*

Methods of study were the same as those employed in the study of *E. olivaceum* (Page 1980:3–5). Minnow-seine collections were made at about 2-month intervals; the first collection was made on 3 March 1977, the last on 30 January 1979. A total of 10 collections were made and 425 specimens were preserved and examined. Specimens collected for study were preserved in 10-percent formalin. Collections were recorded as being made in riffles, bedrock pools, or slab pools. Potential predators captured during seining operations were preserved for later examination of stomach contents. Ambient stream conditions were recorded at each visit.

In the laboratory each specimen was measured (unless stated otherwise, all lengths given in the text are standard lengths), sexed by examining the genital papilla or when necessary the gonads, and aged. Aging to year class was done by counting annuli on scales removed from the dorsum; aging to month was done by using April, the month of the greatest breeding activity, as month zero. Thus a darter collected in July and having one scale annulus was estimated to be 15 months old. For some comparisons, darters were divided into young (through 12 months) and adult (over 12 months) age groups. Ninety-seven specimens of various lengths were weighed to the nearest 0.001 g; functional regressions of weight on standard length were computed following Ricker (1973).

A representative sample of each collection was dissected to identify stomach contents and endoparasites and to note the conditions of the gonads. Weights of the ovaries of 34 females and of the testes of 14 males collected in various months were obtained and recorded as proportions of the total body (including the gonads) weights and of the adjusted body weights (the specimen minus the ovaries, stomach, intestine, and liver); the latter weight is intended to remove variation resulting from the weights of recently ingested food. Mature ova in 10 breeding females were counted. The relative survival of the second-year class was calculated by expressing the number of individuals in that year class as a proportion of the number of individuals in the first-year class. Breeding behavior was observed in individuals transferred to aquaria during the breeding season.

HABITAT

E. simoterum lives in rock- and gravel-bottomed pools, often near riffles and with moderate current, in small to medium-sized streams. In Brush Creek, individuals were

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Cover Illustration.—*Etheostoma simoterum* collected in Brush Creek, Smith County, Tennessee, 16 April 1978. Upper, 52-mm male; lower, 51-mm female.

most common in bedrock pools below riffles and in deep (to 20 cm) crevices in the bedrock (Fig. 2). Few individuals were found in riffles or in slab-rock pools along the margins of the stream.

Fig. 2.—Gravel-strewn crevice in bedrock substrate of Brush Creek, Smith County, Tennessee, 16 April 1978. Crevices are occupied by *Etheostoma simoterum*.

Clean pools with moderate current over bedrock, cobble, or gravel are the characteristic habitat of the adults of most species of *Nanostoma* although Bouchard (1977:124) found *E. etnieri* to be most common in riffles and runs, and *E. zonale* inhabits rocky and usually vegetated riffles. O'Neil & Boschung (1980) stated that *E. coosae* occupies raceways, riffles, and pools over cobble or gravel.

REPRODUCTION

Reproductive Cycle of the Male

During most of the year, the genital papilla of the male is a small conical structure. Between January and April the papilla gradually elongates and becomes tubular (Fig. 3). Testes of breeding males are large, white, and spongy; those of nonbreeding males are small and translucent. The mean testes-to-total-body (including the testes) weight ratio increased from 0.002 (N = 3 males) in October to a high of 0.017 (N = 3) in April. From June to September, when males were postreproductive, the testes were too small to weigh accurately (i.e., less than 0.001 g). The relationship between the mean weight of the testes divided by the adjusted body weight (specimen's body weight after removal of the gonads, stomach, intestine, and liver) and the month, with October = 6 and April = 12, was log Y = 0.697 + 0.169X, with r = 0.986 (Fig. 4).

All April-collected males (N = 19) were 1 year old, had enlarged testes and were considered sexually mature. They ranged from 40.1 to 55.7 and averaged 49.1 mm in length. Sexual maturity at 1 year is usual among darters, although in some species a few individuals may not be large enough by the first breeding season to mature sexually, and in northern populations of some species (e.g., *E. zonale*) individuals may not mature until their second year (Lutterbie 1979:24).

Breeding colors began developing in the largest males in January and by April all males were brightly colored. The breeding male is deep green or blue-green with bright red or red-orange spots on the body and bright red dorsal fins. The red spots on the body sometimes coalesce into suffusions of red or red-orange. Breeding tubercles do not develop.

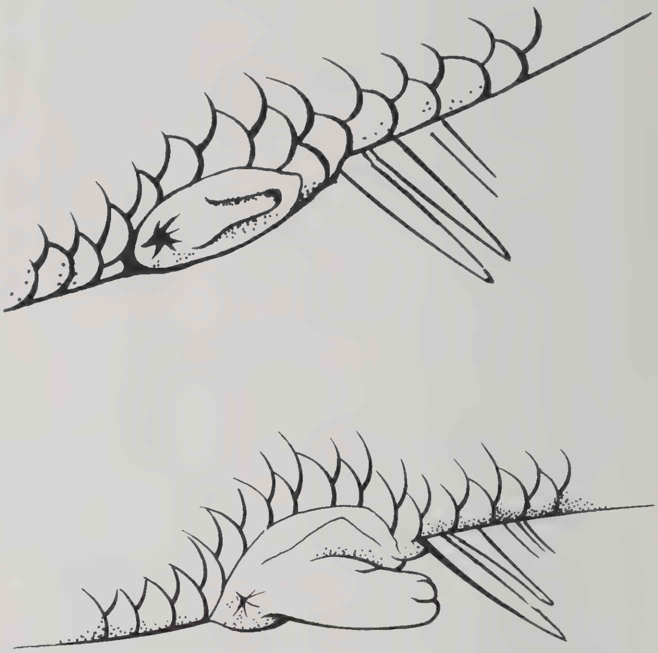

Fig. 3.—Genital papillae of *Etheostoma simoterum* collected in Brush Creek on 16 April 1978. Upper, breeding male; lower, breeding female. Both specimens were 1 year old.

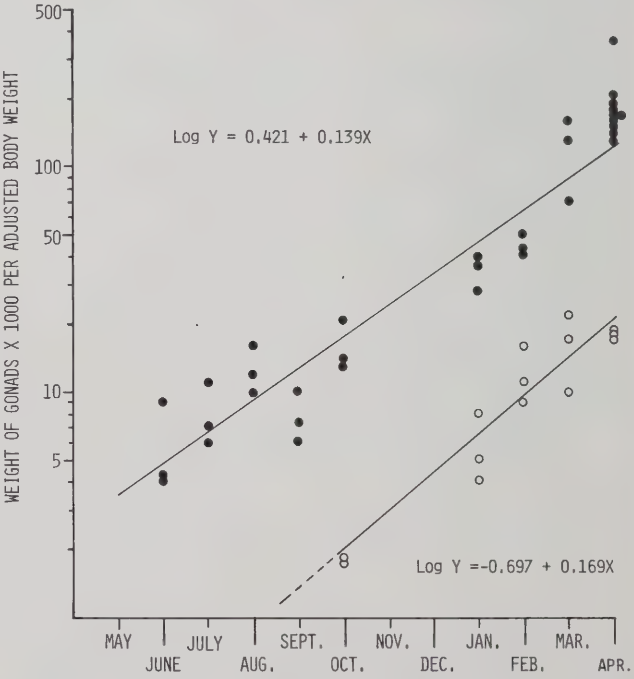

Fig. 4.—Monthly variations in ovarian (dots) and testicular (open circles) weights relative to adjusted body weights in *Etheostoma simoterum*.

Reproductive Cycle of the Female

The genital papilla of the nonbreeding female is a short thick tube. During spring the tube elongates into a structure (Fig. 3) used to attach the adhesive eggs to a suitable substrate (Fig. 5). The breeding female is slightly brighter but nearly identical in color to the nonbreeding female.

Ovaries of June-collected 1-year-old females were in a state of reabsorption and had no mature ova. From July to September the ovaries contained only undifferentiated (clear) ova and were small and translucent. In October the largest females (1 + age class) contained a few differentiated (white) ova. By February yellow ova were present, and in March large, dark yellow, nearly mature ova were present (only -1 age class females were collected after October).

All April-collected females (N = 48) were 1 year old, contained mature ova, and presumably would have spawned within a few weeks. They ranged from 38.5 to 50.8 and averaged 44.1 mm in length. Fully mature ova averaged 1.2 mm in diameter and were transparent with one to several oil droplets and deeply indented on one side. Indented eggs have been described for darters of the subgenera *Microperca* (= *Boleichthyes* — see Page 1981) and *Catonotus* (Burr & Page 1978:6, 1979:5; Page 1980:7) but are not known in other freshwater fishes (Burr & Ellinger 1980).

In 10 females collected on 16 April 1978 the number of mature ova ranged from 110 to 240 (Table 1). As in other darters living through only one breeding season (Burr & Page 1978:6-7, 1979:5-6; Page 1980:7), no significant correlation exists between the number of mature ova produced by a female and the standard length, nor between the number of mature ova and the body weight or adjusted body weight; for all relationships the correlation coefficients (r) were less than 0.32.

Table 1.—Relationship between female size, weight of ovaries, and number of mature ova in *Etheostoma simoterum*. All females were collected in April 1978 and estimated to be 12 months old.

Standard Length in mm	Body Weight in Grams	Adjusted Body Weight in Grams[a]	Weight of Ovaries in Grams	Number of Mature (Orange or Translucent) Ova
42	1.44	1.07	0.18	122
43	1.46	1.15	0.15	110
43	1.41	1.05	0.17	144
43	1.53	1.11	0.20	170
43	1.88	1.27	0.45	240
45	1.60	1.25	0.20	128
47	1.75	1.34	0.28	112
48	2.07	1.57	0.22	188
49	1.93	1.49	0.24	128
51	2.52	2.03	0.38	182

[a] Adjusted body weight is the specimen's weight after removal of the ovaries, stomach, intestine, and liver.

The relationship between the mean weight of the ovaries divided by the total body (including the ovaries) weight (Y) and the month of collection (X), with May = 1 and April = 12, was log Y = 0.402 + 0.133X, with r = 0.963. The relationship between the mean weight of the ovaries divided by the adjusted body weight (Y) and the month of collection (X) was log Y = 0.421 + 0.139X, with r = 0.963 (Fig. 4). The proportionally largest ovaries, equalling 24.0 percent of the body weight or 35.5 percent of the adjusted body weight, were found in a 43.2-mm female collected on 16 April 1978. In the 10 females represented in Table 1, ovary-weight-to-adjusted-body-weight ratios ranged from 0.128 to 0.355 and averaged 0.185.

Spawning

In Brush Creek in 1978, *E. simoterum* spawned in April and probably in early May. Ripe individuals transferred from Brush Creek (19 °C) on 16 April 1978 to a laboratory aquarium were observed spawning the next 2 days (at 25 °-27 °C).

Three males and five females were held in an aquarium on 17-18 April 1978; the two largest males and at least three of the females were observed spawning. Aquarium-held breeding males did not defend stationary territories, but were combative toward one another when in close proximity (within 10 cm). A male courted a nearby female by laterally displaying his erect median fins. During displays the blue-green and red-orange on the side of the body and in the fins were at their greatest intensity. When receptive to the courting of a male, a female led the male to a site selected for egg deposition. The male followed closely behind the female and at the selected site mounted the female (Fig. 5). The pair vibrated and one or two eggs were released and fertilized. Characteristically the pair then moved to another site and repeated the spawning act. However, males and females were promiscuous and repeatedly switched from one spawning partner to another.

Usually eggs were attached to the side of a large stone; less often they were laid on top of a stone. On a few occasions eggs were buried in gravel (Fig. 5); however, the female did not bury her body as deeply into the gravel as do more typical egg-burying species (e.g., *E. caeruleum* — Winn 1958:177). Eggs were not guarded by the parents. Often after laying the eggs in gravel the female immediately turned and ingested them. The related *E. coosae* and two undescribed species of *Nanostoma* also deposit eggs on the surfaces of large stones (Winn 1985:160, O'Neil & Buschung 1980); *E. zonale* lays eggs among filamentous algae in riffles (Pflieger 1975:312).

DEVELOPMENT AND GROWTH

A series of 40 young *E. simoterum* ranging in length from 14 to 32 mm was collected at the study area on 18 June 1977. At 14 mm, the pigmentation was essentially the same as that of the adult and squamation was complete except on the nape and anterior half of the belly. Head canals were complete but the lateral line had not yet

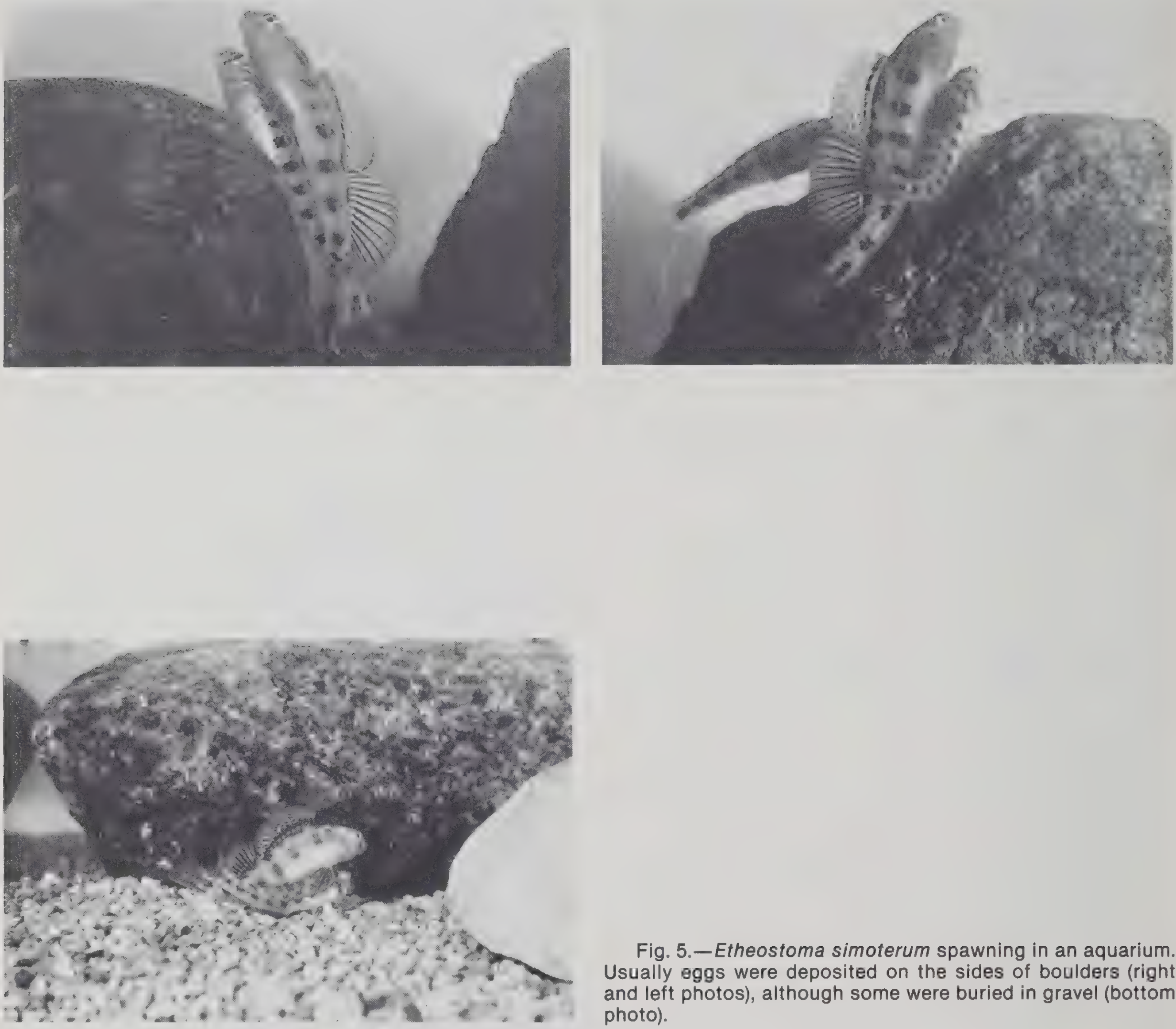

Fig. 5.—*Etheostoma simoterum* spawning in an aquarium. Usually eggs were deposited on the sides of boulders (right and left photos), although some were buried in gravel (bottom photo).

begun to form. On specimens 17-18 mm, the lateral line extended to near the junction of the first and second dorsal fins. At 20 mm the lateral line was complete but the nape and anterior portion of the belly were still unscaled. At 25 mm squamation was complete.

For males, the relationship between mean standard length (Y) and age in months (X) is $Y = 18.4 + 27.66 \log X$, with $r = 0.924$, and for females is $Y = 19.2 + 22.48 \log X$, with $r = 0.933$ (Fig. 6). At 1 year (12 months) males ($N = 19$) were significantly ($t_{cal} = 5.66$, df = 65) longer ($\bar{X} = 49.1$ mm) than females ($N = 48$, $\bar{X} = 44.1$ mm). *E. simoterum* reached one-half of the first year's mean growth in about 8 weeks.

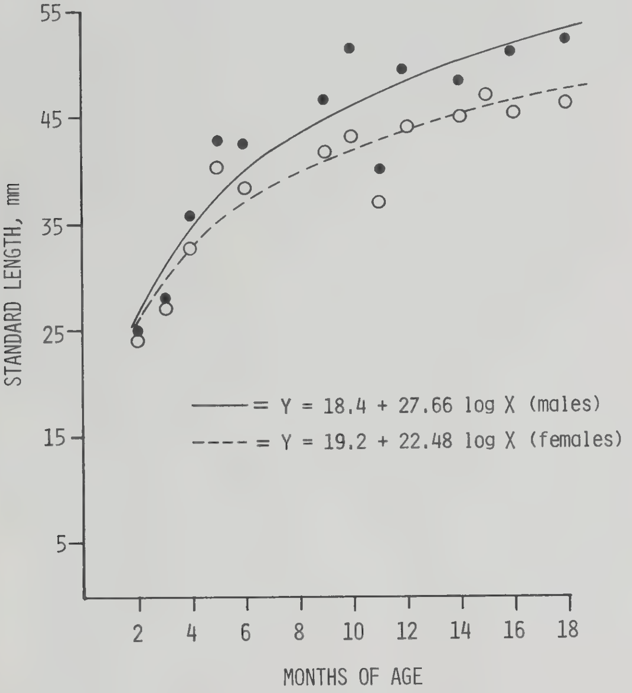

Fig. 6.—Size distribution by age of *Etheostoma simoterum* collected in Brush Creek between 3 March 1977 and 30 January 1979. Black dots represent sample means for males; circles represent sample means for females. A total of 425 specimens is represented.

The largest specimen examined from Brush Creek was a 55.7-mm male collected on 16 April 1978; the largest female was 50.6 mm and collected on the same date. The largest specimen known for the species is 64 mm.

For males ($N = 45$) the functional regression (Ricker 1973) of total weight (W) on standard length (L) was $\log W = -5.116 + 3.196 \log L$, with $r = 0.995$; for females ($N = 52$) was $\log W = -5.209 + 3.255 \log L$, with $r = 0.983$; and for both sexes ($N = 97$) was $\log W = -5.149 + 3.216 \log L$, with $r = 0.990$. A slope above 3 means that the fish grows proportionally heavier as it grows longer (Ricker 1968). Among darters, the largest slopes are found in deep-bodied riffle-inhabiting species such as *E. tippecanoe* (slope = 3.9 — Page & Burr 1979) and *E. caeruleum* (3.4 — Lutterbie 1979:7); the smallest values are found in slender, quiet-water species such as *E. exile*(2.6 — Copes 1976:9) and *E. striatulum* (2.7 — Page 1980:9). The value of 3.2 for *E. simoterum* corresponds to its typical occupation of habitats having moderate but not swift current.

DEMOGRAPHY

Density

Density estimates were made on two dates by repeatedly seining an area of Brush Creek until no *E. simoterum* were present in two consecutive seine hauls. On 10 August 1977, the density of *E. simoterum* in bedrock pool, the preferred habitat, was 5.38 individuals per m^2. On 30 January 1979, densities per m^2 were: in slab pools, 0.0; in riffles, 0.0; and in bedrock pools, 2.61.

Density values given for *E. olivaceum* in Brush Creek (Page 1980:10) were incorrect. Those values should have been, for 10 August 1977: in slab pools, 4.04 individuals per m^2; for 30 January 1979: in slab pools, 8.07; in riffles, 1.79; and in bedrock pools, 1.47. For *E. striatulum* the value should have been 1.34 per m^2.

Composition

Of the 425 specimens collected in Brush Creek between 3 March 1977 and 30 January 1979, 90.1 percent were up to 1 year of age and 9.9 percent were between 1 and 2 years of age (Table 2).

Table 2.—Distribution of sexes and year classes in samples of *Etheostoma simoterum* collected in Brush Creek between 3 March 1977 and 30 January 1979.

Sex	Number by Year Class		Total
	-1	+1	
Males	139	12	151
Females	244	30	274
Total	*383*	*42*	*425*

Females significantly outnumbered males in the first year (-1) age class [1.75 to 1 ($X^2 = 28.79$; $P < 0.001$)] and in the second year (1 +) age class [2.5 to 1 ($X^2 = 35.59$; $P < 0.001$)]. Among all specimens collected, females were 1.81 times as abundant as males ($X^2 = 35.59$; $P < 0.001$). Although females often predominate in the highly territorial species of the subgenus *Catonotus* (Lake 1936:829; Schwartz 1965:100; Page 1974:13, 1975:10; Page & Burr 1976:9), most sex ratios among darters have not deviated significantly from 1:1. More data are needed on *E. simoterum* and on other species of the subgenus *Nanostoma* to determine if the Brush Creek ratio is typical.

Survival

Of the 151 males collected, 92.1 percent were up to 1 year of age and 7.9 percent were between 13 and 18 months of age. Of the 274 females, 89.1 percent were up to 1 year old, and 10.9 percent were between 13 and 18 months of age. Assuming that each year class was collected in proportion to its relative number in the population, only 8.6 percent of the first-year males and 12.3 percent of the first-year females survived to a second year. For males and females combined, survival to a second year was 11.0 percent.

From this 2-year study, it appears that in Brush Creek, *E. simoterum* does not live beyond 18 months and experiences only one spawning season. A maximum longevity of 18 months and a survival rate to a second year of only 11 percent are smaller than the values found for other darters, including *E. proeliare* and *E. microperca* for which short life spans were thought to be a distinctive feature among darters (Burr & Page 1978:11, 1979:11). The largest *E. simoterum* in the fish collection of the Illinois Natural History Survey is a 63-mm male collected in East Fork Stones River, Rutherford County, Tennessee, on 14 March 1976. Scale readings suggest that this specimen, which is only 1 mm less than the length of the largest specimen known for the species, was 2 years (23–24 months) old when captured. The consubgeneric species, *E. coosae* and *E. zonale*, live to 3 and 3 + years, respectively (O'Neil & Boschung 1980; Lachner et al. 1950:101).

DIET AND PARASITISM

Stomach contents of 45 *E. simoterum* were identified and tabulated by size class of darter (Table 3) and month of collection (Table 4). Midge larvae (Chironomidae) formed the bulk of the diet of all size classes. Other major items were mayfly naiads, caddisfly larvae, copepods, and cladocerans. The smallest darters fed mainly on midges, copepods, and cladocerans. With an increase in size, the darters shifted to larger food items, eating fewer crustaceans and more mayflies and caddisflies (Table 3).

Food consumption was high in spring and fall, and highest in April (Table 4), the month of peak spawning activity. Consumption was lowest in January, February, and July, months of temperature extremes and probably of reduced activity by the darters.

In the 45 stomachs examined, 6 contained a total of 12 flukes and 2 contained a total of 3 parasitic nematodes. Flukes were present in individuals collected in February, March, and April; nematodes were present in January and February. All flukes and nematodes were found in large darters (42 mm and longer).

External parasites found on *E. simoterum* from Brush Creek were fluke metacercariae (black-spot disease) and piscicolid leeches. The leeches were found only on darters collected in April 1977, and were present on 7 of 19 darters collected. The metacercariae were present in most months but only on darters 35 mm and longer.

CONTRASTS WITH *ETHEOSTOMA OLIVACEUM*

E. simoterum and *E. olivaceum* are rivaled in abundance in Brush Creek only by midwater minnows (*Pimephales notatus* and an undescribed species of *Notropis*) which do not compete with the darters for space and probably not for food. The only species of darter other than *E. simoterum* and *E. olivaceum* encountered at the Brush Creek study site was *E. flabellare* and it was extremely uncommon. *Cottus carolinae,* the banded sculpin, is a benthic species which might compete with the darters but also was uncommon. In Brush Creek, the most likely competitors for *E. simoterum* and *E. olivaceum* are each other. However, their life-history characteristics suggest a low probability of competition between the two species for resources likely to be in limited supply.

Although sharing the same small stream the two darters occupy different habitats and are not in direct competition for space or food. *E. olivaceum* lives and breeds in the slab-rock pools along the margins of Brush Creek and only rarely is found in bedrock pools. *E.*

Table 3.—Stomach contents of *Etheostoma simoterum* from Brush Creek, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organisms Occurred				Mean Number of Food Organisms per Stomach			
	17–25 mm (6)	26–35 mm (7)	36–45 mm (20)	46–55 mm (12)	17–25 mm (6)	26–35 mm (7)	36–45 mm (20)	46–55 mm (12)
Gastropoda	....	14.3	....	....	....	0.14	....	....
Arachnida								
Acarina	....	....	....	8.3	....	....	....	0.16
Crustacea								
Cladocera	16.7	28.6	15.0	8.3	0.17	7.71	0.35	0.08
Copepoda	33.3	42.9	10.0	8.3	0.50	4.00	0.15	0.08
Insecta								
Ephemeroptera	....	42.9	25.0	33.3	....	0.71	0.70	0.42
Trichoptera	....	14.3	5.0	16.7	....	0.14	1.45	0.50
Diptera								
Chironomidae	100.0	85.7	80.0	91.7	7.50	2.14	24.15	12.17

Table 4.—Stomach contents of *Etheostoma simoterum* from Brush Creek, by month of collection. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organisms Occurred									Mean Number of Food Organisms per Stomach								
	Jan. (5)	Feb. (5)	Mar. (5)	Apr. (5)	June (5)	July (5)	Aug. (5)	Sept. (5)	Oct. (5)	Jan. (5)	Feb. (5)	Mar. (5)	Apr. (5)	June (5)	July (5)	Aug. (5)	Sept. (5)	Oct. (5)
Gastropoda	....	....	....	....	....	20.0	....	....	....	....	....	....	....	....	0.20	....	....	....
Arachnida																		
Acarina	....	....	....	20.0	....	....	....	....	....	....	....	....	0.40	....	....	....	....	....
Crustacea																		
Cladocera	....	....	....	....	20.0	....	60.0	40.0	20.0	....	....	....	....	0.20	....	11.80	0.40	0.20
Copepoda	....	....	....	20.0	20.0	40.0	60.0	....	20.0	....	....	....	0.20	0.20	0.60	5.60	0.60	0.40
Insecta																		
Ephemeroptera	20.0	20.0	20.0	40.0	....	....	80.0	40.0	40.0	0.20	0.40	0.20	0.60	....	....	2.20	....	0.40
Trichoptera	....	20.0	....	40.0	....	....	20.0	....	....	....	0.80	....	6.20	....	....	0.20	....	....
Diptera																		
Chironomidae	80.0	40.0	100.0	100.0	100.0	100.0	80.0	80.0	100.0	5.20	4.20	13.40	66.20	8.00	3.20	4.00	14.40	19.20

simoterum lives and breeds in bedrock pools and crevices and seldom invades the smaller, more shallow slab-rock pools.

The most striking ecological difference, other than habitat, between the two darters is their reproductive behavior. *E. olivaceum* males establish territories beneath slab stones and guard their nests of eggs until hatching. *E. simoterum* does not establish stationary territories, lays eggs over a relatively large area, and immediately abandons them. As would be predicted by the reproductive effort expended (Hoar 1957), *E. olivaceum* produces fewer (60–112) and larger (2.0 mm in diameter) eggs per female than does *E. simoterum* (110–240 eggs averaging 1.2 mm). *E. olivaceum* lives longer (to 27 months) than does *E. simoterum* (18 months) and gets larger (to 14 percent longer). Presumably as a result of its larger size, *E. olivaceum* eats a more varied diet, including some organisms generally too large for *E. simoterum* to ingest (e.g., stonefly naiads, beetle larvae, amphipods, and isopods).

SUMMARY

The life history information on *E. simoterum* collected in Brush Creek between 3 March 1977 and 30 January 1979 is summarized in Table 5.

Table 5.—Summary of life-history information on *Etheostoma simoterum* in Brush Creek.

Characteristic	Life-history Data
Principal habitat	Rock and gravel-bottomed pools with current
Age at reaching sexual maturity	1 year
Age at first spawning	1 year
Size at reaching sexual maturity	All spring-collected individuals regardless of size were sexually mature.
Sexual dimorphism	Males are larger and more colorful.
Number of mature ova counted	110–240
Description of egg	1.2 mm in diameter, translucent, and deeply indented on one side
Spawning period	April and probably early May
Spawning position	Male mounted on back of female
Egg deposition site	Usually the sides and tops of large stones
Egg guarding	None
Influence of sex on growth rate	At 1 year males are significantly larger than females.
Sex ratio	1.8 females: 1 male
Longevity	18 months
Maximum size	55.7 mm standard length for males; 50.6 mm for females
Territoriality	Stationary territories not observed; moving territories may be established by males.
Principal diet	Crustaceans and immature aquatic insects

LITERATURE CITED

Adamson, S. W., and T. E. Wissing. 1977. Food habits and feeding periodicity of the rainbow, fantail, and banded darters in Four Mile Creek. Ohio Journal of Science 77:164-169.

Bouchard, R. W. 1977. *Etheostoma etnieri*, a new percid fish from the Caney Fork (Cumberland) River system, Tennessee, with a redescription of the subgenus *Ulocentra*. Tulane Studies in Zoology and Botany 19:105-130.

Bryant, R. T. 1979. The life history and comparative ecology of the sharphead darter, *Etheostoma acuticeps*. Tennessee Wildlife Resources Agency Technical Report No. 79-50.60 p.

Burr, B. M., and M. S. Ellinger. 1980. Distinctive egg morphology and its relationship to development in the percid fish *Etheostoma proeliare*. Copeia 1980:556-559.

______, and L. M. Page. 1978. The life history of the cypress darter, *Etheostoma proeliare*, in Max Creek, Illinois. Illinois Natural History Survey Biological Notes 106. 15 p.

______, and ______. 1979. The life history of the least darter, *Etheostoma microperca*, in the Iroquois River, Illinois. Illinois Natural History Survey Biological Notes 112. 15 p.

Copes, F. A. 1976. The Iowa darter *Etheostoma exile* Girard. American Currents 4:2-10.

Cordes, L. E. and L. M. Page. 1980. Feeding chronology and diet composition of two darters (Percidae) in the Iroquois River system, Illinois. American Midland Naturalist 104:202-206.

Forbes, S. A., and R. E. Richardson. 1908. The fishes of Illinois. Illinois State Laboratory of Natural History. cxxxi + 357 p.

Hoar, W. S. 1957. The gonads and reproduction. Pages 287-321 *in* M. E. Brown, ed., The physiology of fishes. Academic Press, New York.

Lachner, E. A., E. F. Westlake, and P. S. Handwerk. 1950. Studies on the biology of some percid fishes from western Pennsylvania. American Midland Naturalist 43:92-111.

Lake, C. T. 1936. The life history of the fan-tailed darter *Catonotus flabellaris flabellaris* (Rafinesque). American Midland Naturalist 17:816-830.

Lutterbie, G. W. 1979. Reproduction and age and growth in Wisconsin darters (Osteichthyes: Percidae). University of Wisconsin Museum of Natural History Reports on the Fauna and Flora of Wisconsin No. 15. 44 p.

Miller, R. J., and H. W. Robison. 1973. The fishes of Oklahoma. Oklahoma State University Press, Stillwater. 246 p.

O'Neil, P., and H. Boschung. 1980. Life history aspects of *Etheostoma coosae* (Pisces:Percidae) in Barbaree Creek, Clay County, Alabama. Association of Southeastern Biologists Bulletin 27:53.

Page, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps*, in Big Creek, Illinois, and Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 89. 20 p.

______. 1975. The life history of the stripetail darter, *Etheostoma kennicotti*, in Big Creek, Illinois. Illinois Natural History Survey Biological Notes 93. 15 p.

______. 1980. The life histories of *Etheostoma olivaceum* and *Etheostoma striatulum*, two species of darters in central Tennessee. Illinois Natural History Survey Biological Notes 113. 14 p.

______. 1981. The genera and subgenera of darters (Percidae, Etheostomatini). Occasional Papers of the Museum of Natural History of The University of Kansas 90. 69 p.

______, and B. M. Burr. 1976. The life history of the slabrock darter, *Etheostoma smithi*, in Ferguson Creek, Kentucky. Illinois Natural History Survey Biological Notes 99. 12 p.

______, and ______. 1979. The smallest species of darter (Pisces: Percidae). American Midland Naturalist 101:452-453.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation. 343 p.

Ricker, W. E. 1968. Methods for assessment of fish production in fresh waters. International Biological Program Handbook 3. 313 p.

______. 1973. Linear regressions in fishery research. Canadian Fisheries Research Board Journal 30:409-434.

Schwartz, F. J. 1965. Densities and ecology of the darters of the upper Allegheny River watershed *in* C. A. Tryon, Jr., R. T. Hartman, K. W. Cummins, eds., Studies on the aquatic ecology of the upper Ohio River system. Pymatuning Laboratory of Ecology, University of Pittsburg, Special Publication 3.

Wehnes, R. A. 1973. The food and feeding interrelationships of five sympatric darter species (Pisces: Percidae) in Salt Creek, Hocking County, Ohio. M. S. Thesis, Ohio State University. 79 p.

Winn, H. E. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecological Monographs 28:155-191.

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